June 2002 www.nasatech.com Vol. 26 No. 6

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

NASA's Inventions of the Year

Automation Software Enables Advanced Electronic Design

NASA Failure-Reporting Device Mimics "Black Box" Data Recorders

Photonics Tech Briefs

Motion Control Tech Briefs

CO_2 Laser Applications of the Month

SYNRAD®
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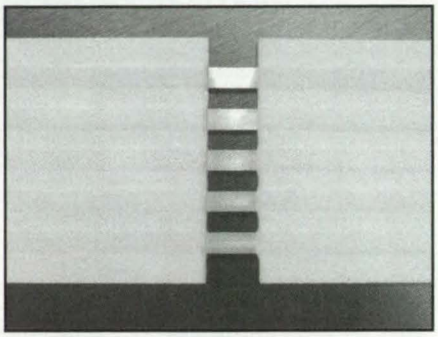
Wire Stripping with Sealed CO_2 Lasers



Clean results were achieved with a 25-watt Synrad CO_2 laser.

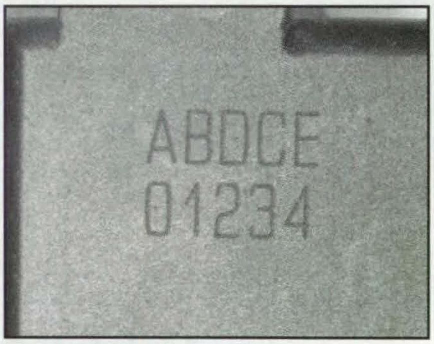
Because many materials used to fabricate wires, such as copper and aluminum, are reflective to the CO_2 wavelength, lasers are an excellent source for wire stripping. The laser ablates the coating, typically consisting of PVC, Teflon, Mylar, etc., and the laser beam reflects off the copper, leaving the underlying wire undamaged. Unlike traditional contact cutting methods, which can lead to product damage, the laser produces clean results.

The wire stripping application in the photo to the left was accomplished by scanning a 0.6" x 0.15" area with a Synrad FH "Index" marking head and 25-watt laser. Two passes of the laser were used at a speed of 40" per second and a resolution of 350. The process was then repeated on the other side of the material, resulting in a cycle time of 2.3 seconds per side.

Laser Marking Plastic Automotive Parts

Sealed CO_2 lasers are ideal for marking text, bar codes, and serial codes on a wide range of plastics. The type of plastic, absorption of the laser beam, and power used will determine the type of mark that can be created on the material.

Marking is achieved by either engraving the material or by creating a contrasting mark on the surface. Engraved marks are produced when the laser actually removes material, creating a depression. Contrasting marks are produced by either surface melting or by surface discoloration via a chemical reaction of the material to the laser beam, usually requiring less power than engraving.



Engraved marks can be created on plastic parts using just 10-watts of laser power.

The engraved alphanumerics on the plastic automotive part in the photo to the left were created using a Synrad 10-watt laser, marking head, and 125mm lens. The marks were made at a speed of 5" per second and a cycle time of 0.75 seconds, using a spot size of 180 microns.

Laser "Engraving" Polyester Fleece

The pile of this polyester fabric can be selectively removed to create a pattern or logo on the material with no discoloration. An alternative to interweaving the pattern into the fleece, the laser offers manufacturers excellent flexibility on logo positioning and design.

Polyester fleece, "engraved" with a Synrad 10-watt laser and FH-Series "Index" marking head.

Discover more CO_2 laser applications! Sign up for our online Applications Newsletter at ***www.synrad.com/signup1***

*All applications on this page were processed at **Synrad's Applications Laboratory**. Synrad, the world's leading manufacturer of sealed CO_2 lasers, offers free process evaluations to companies with qualified applications. Call 1-800-SYNRAD1 for more information.*

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Now the left hand knows what the right hands are doing.

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SPECIAL SUPPLEMENT

Follows page 40 in selected editions only.

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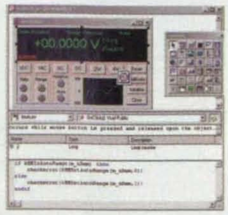
PRODUCT OF THE MONTH

ATEasy 4.0 test development software from Geotest-Marvin Test Systems (Irvine, CA) lets users create re-usable components modeled after real-world test systems.



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ON THE COVER

The DeBakey Ventricular Assist Device (VAD) rotary blood pump, developed at Johnson Space Center, was named NASA Commercial Invention of the Year for 2001. The use of computational fluid dynamics (CFD) modeling, coupled with computing technology from NASA's Advanced Supercomputing (NAS) division at Ames Research Center, led to design modifications that improved the VAD's performance. This image shows a visual comparison of the original VAD (right), and the unit following the addition of an inducer. Read more about the pump, as well as NASA's Government Invention of the Year, beginning on page 30.

(Image courtesy of NASA/Cetin Kiris)

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Information Technology; Biotechnology; Nanotechnology; Aerospace Operations Systems; Rotorcraft; Thermal Protection Systems.
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Dryden Flight Research Center
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Langley Research Center
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John H. Glenn Research Center at Lewis Field
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Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Vernotto McMillan
(256) 544-2615
vernotto.mcmillan@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
kirk.sharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

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National Technology Transfer Center
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Ken Dozier
Far-West Technology Transfer Center
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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Wayne P. Zeman
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Cleveland, OH
(216) 586-3888

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

Julie Holland
NASA Commercialization Center
Pomona, CA
(909) 869-4477

Bridgette Smalley
UH-NASA Technology Commercialization Incubator
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John Fini
Goddard Space Flight Center Incubator
Baltimore, MD
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Thomas G. Rainey
NASA KSC Business Incubation Center
Titusville, FL
(407) 383-5200

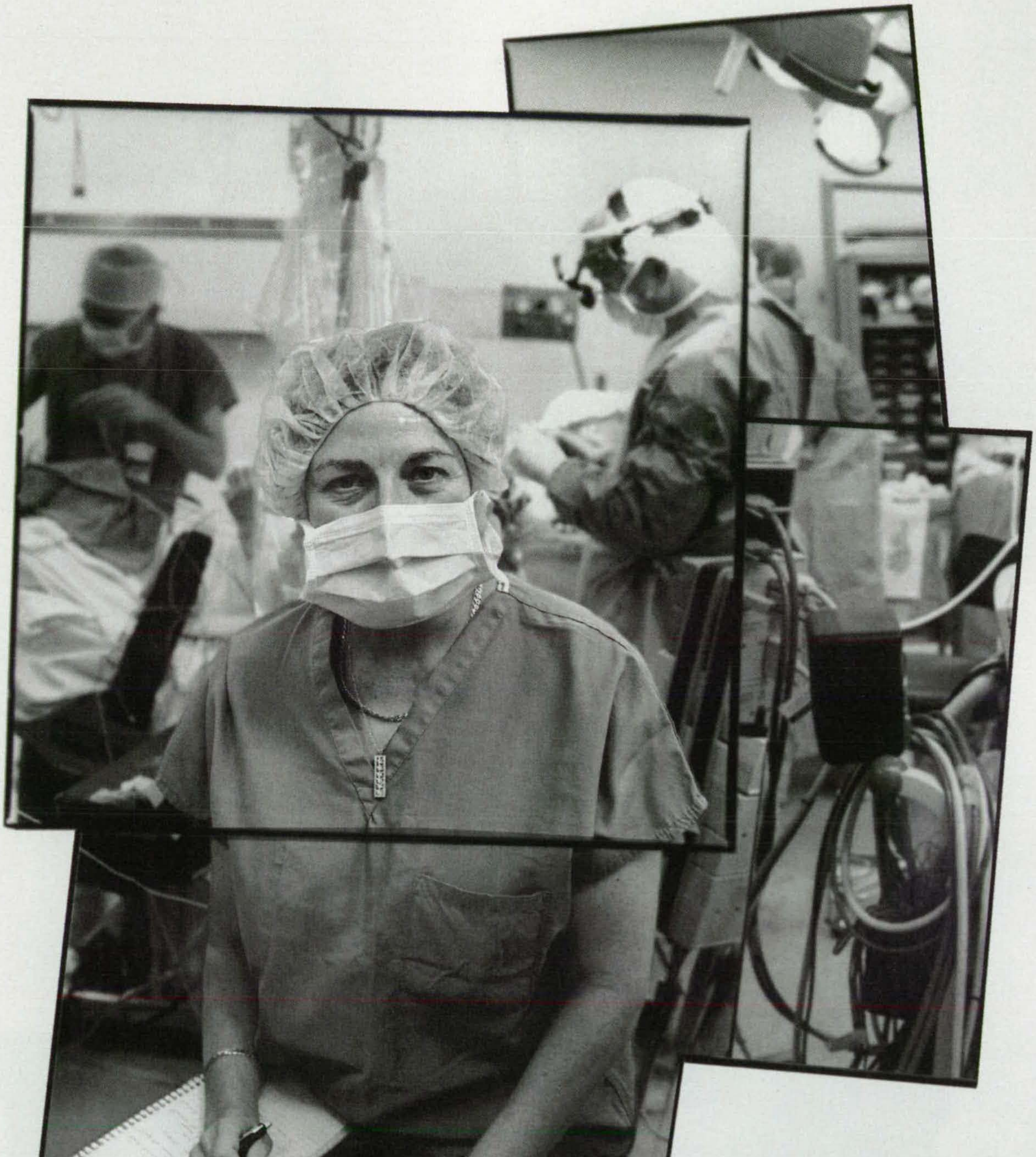
Joanne W. Randolph
BizTech
Huntsville, AL
(256) 704-6000

Joe Becker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Marty Kaszubowski
Hampton Roads Technology Incubator (Langley Research Center)
Hampton, VA
(757) 865-2140

Paul Myrda
NASA Illinois Commercialization Center
West Chicago, IL
(630) 845-6510

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

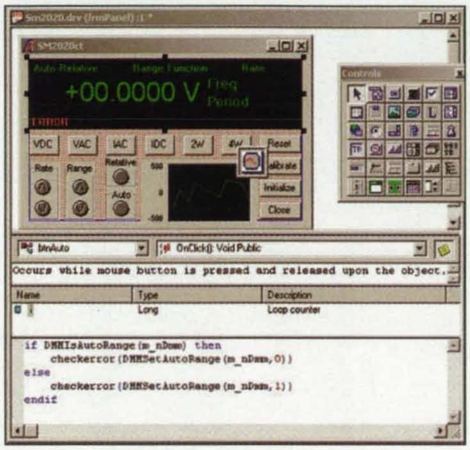



too few software seats
insufficient compute time
simulation uncertainties
incorrect analysis
market window closing
need larger team
not enough experts

UpFront

PRODUCT OF THE MONTH

Geotest-Marvin Test Systems, Irvine, CA, has released ATEasy 4.0 test development software for most test and measurement applications. It lets users create reusable components modeled after real-world test systems. Components include systems, drivers, programs, tests, and commands. The graphical user interface is compatible with Microsoft Visual Basic™ and Visual C++™. The software's modular structure allows users to partition and organize test code. A just-in-time compiler gathers only the necessary code to be executed independently without running the entire application. ATEasy features an open system architecture that provides ActiveX controls, spreadsheets, databases, word processors, and Web browsers. A Test Executive module selects and runs a test program, and debugs, views, and prints test logs.



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What's New On-Line

The *NASA Tech Briefs* Software Center is now open on the NTB Web site at **www.nasatech.com/software** . The Software Center is a new FREE download service that lets you access NASA software programs and source code available for commercial applications and development, ranging from aerodynamic analysis to viscosity measurement. *NASA Tech Briefs* readers also will be able to purchase commercial engineering software directly from the site.

Currently, the Software Center features software code from NASA's Glenn Research Center. But check back often as we continue to add more programs from NASA's other field centers around the country, as well as demos of new commercial software packages.

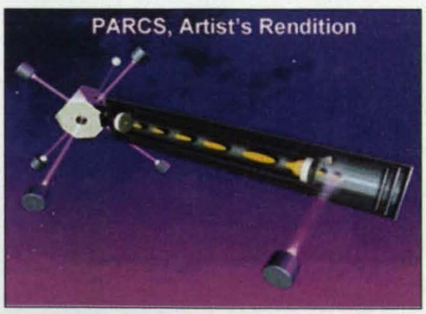
The Software Center also highlights software-related tech briefs, archived software reviews from *NASA Tech Briefs*, and feature articles on software topics that have appeared recently in NTB.

Check it out at **www.nasatech.com/ software** .

NASA's New Atomic Clock Will Aid Farmers and Physicists

Modern navigators continue to rely on atomic clocks that use the natural resonance of atoms to provide the steady tick of a clock. The best atomic clocks on Earth lose no more than one second in millions of years. Scientists at NASA's Fundamental Physics Program would like to do better.

Sailors, truck drivers, soldiers, pilots, and hikers all rely on atomic clocks by using Global Positioning System (GPS) devices. Each of the 24 GPS satellites carries four atomic clocks. Tiny instabilities in those orbiting clocks can contribute a few meters of error to single-receiver GPS measurements. Making the clocks smaller and increasing their stability could reduce such errors.


PARCS, Artist's Rendition

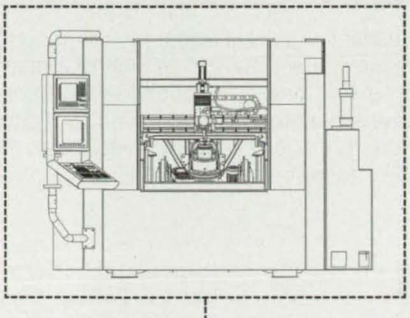
A laser-cooled clock called PARCS is expected to be installed on the International Space Station by 2005. It should be the most stable clock ever, keeping time within one second every 300 million years. PARCS will test technologies to be used in a next-generation clock named RACE slated for installation on the ISS in 2006. RACE will keep time so well that if it ran for three billion years, it would lose less than one second.

Clocks like PARCS and RACE will improve telecommunications on Earth, including navigation. Pilots landing on narrow airstrips at night would benefit, as would surveyors, farmers, and search and rescue teams.

For more information, visit **http://link.abpi.net/l.php? 20020416A2** .

Next Month in NTB

The focus will be on Automotive Technology in the July issue of *NASA Tech Briefs*, with a feature article on auto design and manufacturing, including the newest players in automobile design, simulation, and analysis. Also look for new NASA innovations in sensors and actuators.



Sooner or later, every design becomes 3D.
This is an argument for sooner.

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Reader Forum

Reader Forum is dedicated to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a technical problem, or an answer to a previously published question, post your letter to Reader Forum on-line at **www.nasatech.com,** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and e-mail address or phone number.

I am writing in response to a letter in the March Reader Forum from Michael Jones, who was looking for suggestions on developing a wireless video system. I believe the poor results he's experienced so far are due to multi-path fade and echoes. I suggest a reflector behind the receiving antenna, with about .2 wave separation, and diversity in the form of two antennas some distance apart with the feed lines exactly the same length to the "T". The power/bandwidth allocations in that frequency range are rather stringent.

dave@diamondtouch.com

I'm looking for a device that when placed onto a cargo container, transmits an active signal if the container is tampered with or breached. It would need to be tracked throughout the world. Thank you.

Dave Fulbright
j.fulbrig@jcpenney.com

*(**Editor's Note:** Dave, NASA's Jet Propulsion Laboratory in Pasadena, CA, has developed such a device. The credit-card-sized transponder is placed on a cargo container and can be tracked anywhere on Earth. You can access the complete tech brief on this technology by visiting the* NASA Tech Briefs *library at:* ***www.nasatech.com/Briefs/Sept98/NPO19769.html*** .)

Technologies Wanted

Periodically in Reader Forum, we feature abstracts of Demand-Pull Technology Transfer projects. These projects identify technology needs within an industry segment — such as Augmentative Communication — and find solutions to meet those needs. The Rehabilitation Engineering Research Center on Technology Transfer, in partnership with the Rehabilitation Engineering Research Center on Communication Enhancement and the Federal Laboratory Consortium, has developed the Project on Communication Enhancement to identify technologies like those listed below to help persons with communication disabilities who use Augmentative Communication devices. For more details on the project, or to submit technology proposals, visit **http://cosmos.buffalo.edu/aac.**

Speech Production & Output Technology

Output technologies (speech synthesis, sound projection, and adaptive volume control), are needed that are intelligible, personalized, and natural-sounding to enhance communication privacy. Display technologies are needed that perform well in all lighting conditions and support private communication at short range or remotely.

Speech synthesis technology should produce a natural-sounding voice that can express emotion. It should be customizable and modifiable in real time. Automatic volume control should recognize ambient sound levels; the user should be able to adjust loudness and turn on/off.

Displays should reduce or eliminate daylight glare and improve contrast for night viewing. Displays that automatically adapt to changes in lighting conditions also are desired. Third-party intervention should not be required to set-up, adjust, or take down the display.

Wearable, remote, and dual displays are sought to enhance opportunities for education, rehabilitation, safety, and personal independence. Wireless wearable displays should be unobtrusive and provide a high-quality image. It should not obstruct face-to-face interaction.

Directed sound output (speakers) should automatically track the communication partner to increase intelligibility and communication privacy.


IF YOU CAN THINK IT, WE CAN DO IT.

Who's Who at NASA

Dr. Paul Schenker, Director, Planetary Robotics Laboratory, Jet Propulsion Laboratory

Dr. Paul Schenker is the director of the Planetary Robotics Laboratory (PRL) at NASA's Jet Propulsion Laboratory in Pasadena, CA. The organization is responsible for research and development in mobility and robotics, and is developing a series of rover prototypes for planetary surface exploration.

***NASA Tech Briefs:* What is the purpose of the rovers?**

Dr. Paul Schenker: The purpose is to develop new rovers and supporting technology that could go into more difficult terrain that is rough and sloped. Current rovers have a hard time traveling through rocky, dense areas, or up slopes that are more than 15-20 degrees. It's now thought that some of the most exciting planetary science will be near water outflows at craters' edges. We want to drive rovers up or down to such an area to get to the interesting science.

NTB: How have these rovers performed in demonstrations?

Schenker: They've done well. We first developed the technology in the laboratory. That technology includes not only re-configurable rovers — meaning ones that could change their shape and the positioning of their mechanical parts, their legs, structure, and wheels — but new algorithms that can take what the rovers see, literally, and adapt their control and traction as they go into steeper areas. It's similar to how a human or a dog changes footing, squats down, and gets prepared to go up or down a steep hill.

We give the rover behaviors or skills whereby it can adapt when it sees a region with its computer vision or 3D terrain mapping. So it's kind of an animal-like paradigm, but a rather intelligent one.

NTB: What's the newest prototype?

Schenker: The more exciting aspect of this project is the development of the Cliff-bot. It's not one robot, but three. This is a true robot team with distributed intelligence and sensing. Two of the robots are at the top of the cliff and they are referred to as the Anchor or Tether-bot, which assist the Cliff-bot. There are tethers attached to the Cliff-bot, forming a triangle — two at the top and then the two tethers going down. The robot that is going up and down the cliff is actively driving; it's not just being lowered. A good analogy would be a human climber with two expert assistants.

What is very exciting about that in terms of applications is the promise of a robot being able to go to these very steep cliff edges where there might be mineral water outflows. Using these rovers, we can look where we've never been able to go before.

NTB: Do you foresee any terrestrial applications?

Schenker: Absolutely. The onboard intelligence, or the autonomy, is the research basis for making robots smarter. I think we'll see the robot team idea have importance in things like military applications and for search and rescue. If someone is in trouble, you can deploy a robot into a difficult region. We haven't done anything like that for terrestrial applications. Our work has been NASA-based, but these technologies are potentially important for terrestrial and military applications.

NTB: What is the goal of the Planetary Robotics Laboratory?

Schenker: The PRL is an organization of about 85 people whose interests include the broad range of technology for both NASA and non-NASA robotics. The expertise here spans machine vision, robotic navigation, onboard robotic autonomy, operation interfaces, and mechanical design. Another project is robot-assisted microsurgery (RAMS), which is a system for dexterity-enhanced microsurgery. The surgeon makes a teleoperated input, so when the surgeon's hand moves, it scales the surgery down by a factor of ten and filters out the tremors, allowing doctors to do remarkable surgery. That technology is now on its way to market.

*A full transcript of this interview appears online at **www.nasatech.com/whoswho**. Dr. Schenker can be reached at schenker@helios.jpl.nasa.gov.*

Technologies of the Month

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For more information on these and other new, licensable inventions, visit www.nasatech.com/techsearch

Water-Repellent Technology Can Be Controlled By Light

Hitachi, Ltd.

Waxes, oils, and other coatings have been used to create water-repellent products; however, these coatings evaporate over time, leaving a surface unprotected. A new compound provides an increase in water repellency for a range of materials and products by creating a surface coating offering a contact angle with water of approximately 80-120°. This enables round water droplets to hit the slanted surface and roll off before being absorbed.

A novel feature of this technology is the ability to control its degree of water repellency by applying a photochromatic compound to the coating material. By applying light to certain areas, the chemical structure of the compound can be altered, affecting its ability to interact with water by creating an acid or a base. Applications include anti-corrosion coatings, electronics packaging, anti-icing treatments, and fabric coatings.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/hitachi.html
Email: nasatech@yet2.com
Phone: 617-557-3837

High-Speed Replicator Synchronizes Data Updating Between Relational Databases

The Dutch Royal PTT Post

All the information produced since the dawn of recorded history equals approximately 18 terabytes — the number 18 followed by 18 zeroes. Twelve percent of that data was created in 1999 alone. Databases have become the core of most operations, and the upkeep and feeding of them accounts for increasingly large amounts of time, money, and manpower.

A commercial middleware called High Volume Replicator (HVR) replicates data between databases at extremely high speeds, enabling changes made to one set of data to affect and update those changes to relational databases. HVR offers mission-critical fault tolerance, collision resolution, and database/transaction consistency with 24-hour availability. It also guarantees zero downtime and complex synchronization across diverse platforms and operating systems. The middleware features a Java-based graphical user interface and supports HP-UX, Solaris, AIX, Open VMS, and Windows 2000.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/royalPTT.html
Email: nasatech@yet2.com
Phone: 617-557-3837

New Electrode Layering Technology Substantially Reduces Noise

Toyota

The static a driver hears on a car radio or occasional glitch in the automotive electrical system is often the result of ignition noise — unnecessary electrical signals generated by the distributor and spark plugs in a car's ignition system. As the rotor electrode in the distributor rotates, the discharge between it and the electrodes that send current to the spark plugs creates a high-frequency signal, causing ignition noise.

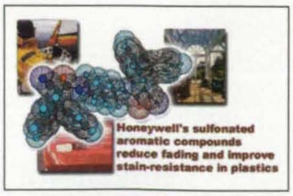
To combat this problem, Toyota has developed a multiple-layer electrode that reduces ignition noise and resists deterioration that can lead to noise creeping back in. The electrode is comprised of two layers, each composed of a metal oxide resistor and dielectric. The second layer features greater resistivity than the first, enabling a lower discharge voltage, which in turn reduces ignition noise. No additional materials or circuitry are required to reduce ignition noise levels, and less expensive materials can be used to replace conventional ceramic electrodes, cutting material and labor costs.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/toyota.html
Email: nasatech@yet2.com
Phone: 617-557-3837

New Stabilizers Improve Appearance and Lengthen Life of Plastics

Honeywell

Though plastic is relatively strong, lightweight, and versatile, its lifespan is shortened when exposed to sunlight, temperature fluctuations, and staining. A group of stabilizers from Honeywell utilizes a class of water-soluble sulfonated aromatic compounds that promise improved stain resistance and reduced fading.



When used to treat nylon fibers, the compounds are applied to the dyed fiber in a diluted or concentrated aqueous solution. The water is then removed and the fibers are oven-dried at 120°C. To improve the fiber's soil resistance, a fluorinated dry soil release agent can also be applied, either before or after the sulfonated aromatic compound application. To reduce fading, the fibers can be treated with cinnamamide compounds, which have the ability to absorb both UV-A and UV-B radiation, enabling polymer fiber to better withstand haziness, brittleness, and general loss of elasticity.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/honeywell-stabilizers.html
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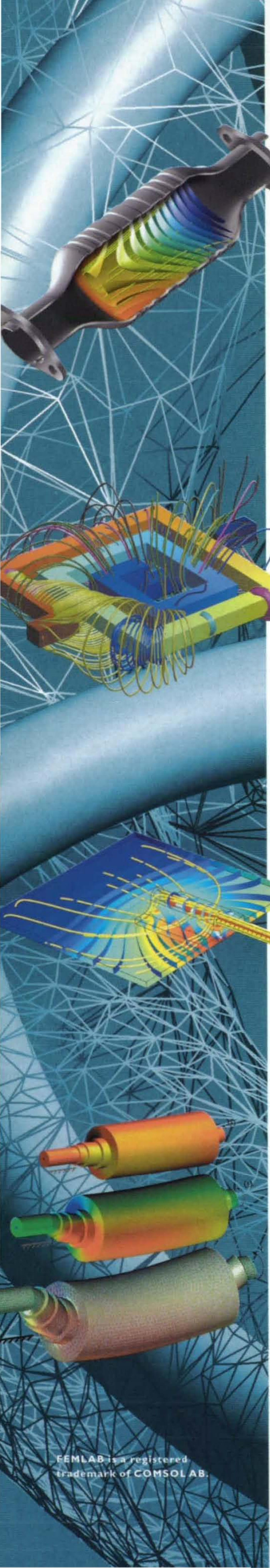

◀ The most common reactor for environmental protection, which we encounter or use everyday, is the catalytic converter in automobiles. In these monolithic catalysts, carbon monoxide and nitrous oxides are converted into relatively harmless species like carbon dioxide and nitrogen. To optimize the utilization of the expensive catalyst, it is important to be able to model the reactor at different operational conditions. In this FEMLAB model, mass and heat balances are coupled to compute temperature distribution and flowlines in the reactor.

◀ This square-shaped spiral inductor is used for bandpass filters in micro electromechanical systems (MEMS). The FEMLAB simulation takes the nonuniform current density in the coils into account to compute an accurate magnetic flux arround the coils. The inductance of this inductor is 2.1 nH, which is obtained by integrating the magnetic energy. Using the programming language of FEMLAB for parametric analysis, you can find the correlation between the induction and the input parameters of the model.

◀ In the design of electrodes for water electrolysis, it is important to minimize the voltage losses at a given total current. FEMLAB modeling helps the engineer in the design of the electrode geometry and the current collector. The model gives the current density distribution and the potential distribution in the system. These results make it possible to avoid excessive degradation of the active electrode surface and overheating of the welds at the position of the current collector.

◀ When designing an electric motor it is important to design the rotor shaft so that no eigenfrequencies exist in the working range of the rotational speed. It is also important to study the shape of the eigenmode and not just the eigenfrequencies. In the eigenfrequency analysis, one end of the shaft is fixed and the other end is free to rotate and axially deform. The image shows deformation and rotation angle in the second eigenmode, using different visualization options like colormaps and scaling.

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- Powerful solvers for linear, nonlinear and time-dependent systems of partial differential equations (PDEs)
- Extensive postprocessing capabilities
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- Ready-to-use application modes for different engineering fields
- Equation-based modeling for arbitrary systems of PDEs

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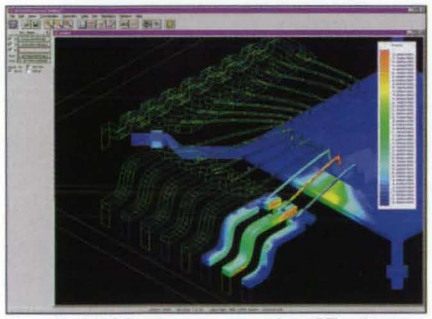
Automation Software Enables Advanced Electronic Design

A thriving industry supports innovation across markets and product types.

Electronic design challenges affect companies in almost every industry including consumer products, automotive, communications, and biomedicine. Perhaps that is why electronic design automation (EDA) blossomed into a $4 billion dollar industry last year despite the troubled economy, according to the EDA Consortium's Market Statistics Service (MSS). That's a 6% increase over 2000 revenues. In fact, since the EDA Consortium started tracking revenue in 1994, the EDA market hasn't experienced a single year of negative growth.



Ansoft HFSS screen sample. 3D electromagnetic field radiation through a high-speed package.

Ray Bingham, EDA Consortium chairman and president, explained, "Even though the electronics industry experienced the worst economic downturn in its history last year, our customers around the world continued to increase their investments in the design of electronic products. That's because product design technologies and services play a crucial role in helping companies create value, differentiate their product offerings, and bring innovation to reality while accelerating time to market."

Industry of Specialties

The EDA Consortium — an international, non-profit association for companies developing design software and services that enable engineers to create the world's electronic products — divides the 16-year-old industry into five main application segments: Computer-Aided Engineering (CAE), Integrated Circuit (IC) Layout, Printed Circuit Board (PCB) & Multi-Chip Module (MCM) Layout, Services, and Semiconductor Intellectual Property (SIP) Products & Tools. Working together, EDA providers structure packages to target a combination of specific market and design subsegments. These companies often provide highly specialized software tools and/or systems that enable complex designs to be realized.

Electronic products are becoming more feature-rich and the number of transistors on an IC is growing exponentially. This necessitates the highly specialized, team-based environments that characterize the design process. As Pamela Parrish, executive director of the EDA Consortium, pointed out, "The bottom line is that consumer demand for more 'gee wiz' features has increased the complexity of designs. We no longer have one engineer designing an entire IC, for example. A team consisting of engineers with differing expertise is needed to create the design using specialized EDA tools."

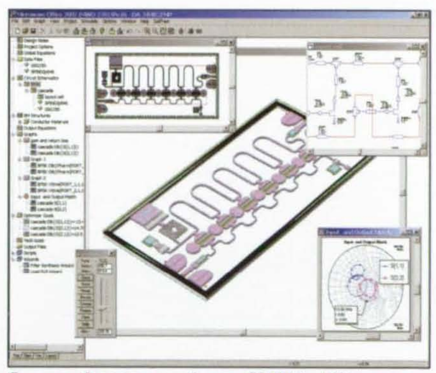
Just as a single engineer cannot provide all the necessary expertise for most design projects, one software company cannot provide all the solutions necessary for every segment of design. Thus, a majority of EDA software companies create some level of interoperability between their solutions and those of other companies. Some alliances are even branded through formalized partnership programs.

Align to Design

"Connection programs like Cadence's Connections® Program and Mentor's OpenDoor are inherent to the EDA industry. After all, EDA stands for electronic design automation and to do that requires data flow and transfer to and from various tools, whether it is hardware or software," added Sherry Hess, vice president of marketing for Ansoft Corporation, a provider of simulation software and member of Cadence Design Systems' Connections program. Hess also noted that a major advantage of these programs is that they remove duplicity from the design cycle, thereby creating significant time-savings and reducing errors associated with manually handling data.

A supplier of electronic hardware and software design solutions, Mentor Graphics' previously mentioned OpenDoor program consists of more than 95 companies that develop and maintain commercial integrations with Mentor for design processes including PCB layout and IC design. Mentor maintains relationships with Ansoft and Cadence through this program.

Cadence, a supplier of EDA products and methodology/design services for semiconductors, computer systems, networking/telecommunications equipment, consumer electronics, and other electronics-based products, provides over 120 members of the Connections Program with access to software and application notes that enable tool interoperability with third-party software. Through the program, Cadence developed interoperability with several Ansoft products. Traces from Cadence software such as APD, a constraint-driven layout environment for the physical design of complex, high-density IC packages, and



A sample screen from AWR's Microwave Office 2002 during a MMIC design project.

Allegro™, a physical and electrical constraint-driven system for the physical design of multi-layer PCBs, can be exported into Ansoft computational analysis tools such as HFSS™ and Maxwell® Spicelink. Originally introduced in 1990, Ansoft HFSS™ provides 3D electromagnetic (EM) simulation for radio frequency (RF), wireless, packaging, and optoelectronic design. Maxwell® Spicelink per-

Collaborate to innovate—PLM Solutions

Product Lifecycle Management (PLM) solutions reduce the complexities and restrictions linked to product manufacturing. How? By providing the framework and tools that foster a collaborative, integrated, end-to-end, process-centric environment. In short, PLM brings together the entire network of companies that conceptualize, design, manufacture and support a product to work together as one single entity.

Improved collaboration leads to better end products. Promoting real-time data exchange between all parties in the product manufacturing process helps define best practices and methodologies. So, rather than reinventing the wheel each time, your whole team gets to concentrate on manufacturing higher-quality, more innovative products. End result: reduced development costs, faster speed to market, maximized profitability and increased customer loyalty.

IBM and Dassault Systemes

Together, IBM and Dassault Systemes offer you leading PLM solutions. IBM is the largest e-business solutions provider, with industry proven technologies and implementation skills. It provides the foundation and support for an unrivalled 3D PLM applications portfolio from Dassault Systemes, including CATIA, ENOVIA and SmarTeam. Companies worldwide have already integrated and streamlined their product management processes with the help of a PLM solution from IBM and Dassault Systemes.

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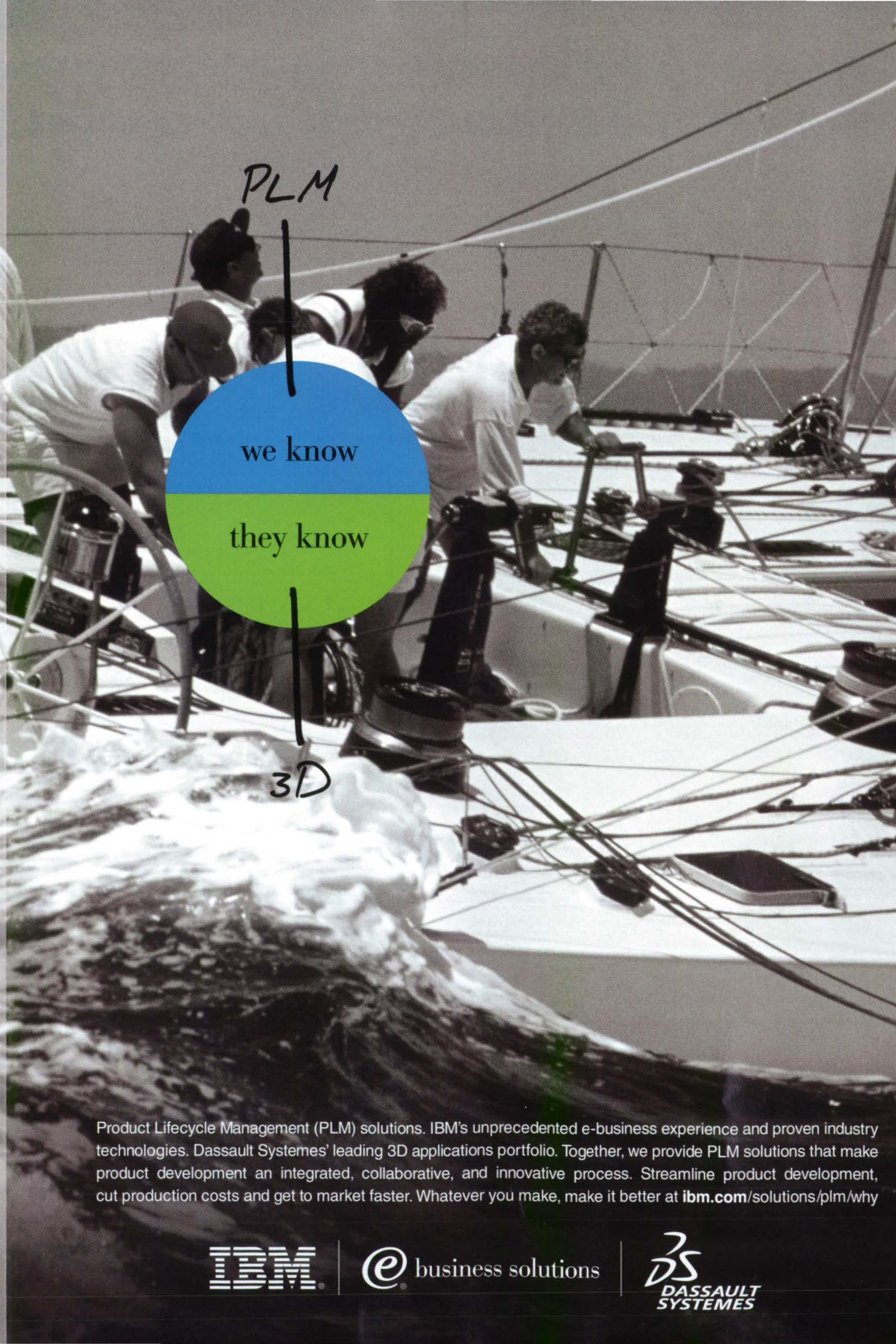
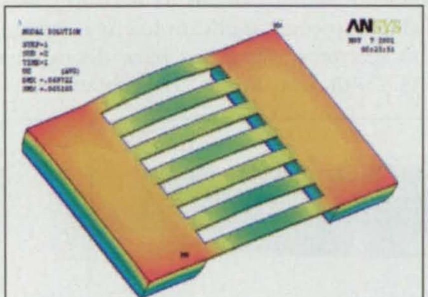


forms electromagnetic field simulation of 2D and arbitrary 3D structures.

In April, Applied Wave Research (AWR), developer of EDA software for wireless, high-speed wireline, and electro-optical applications, also joined the Cadence Connections Program. AWR plans to integrate their Microwave Office 2002 design suite, which consists of an IC layout editor as well as harmonic balance and EM simulators, with Cadence's Analog Design Environment™, an analog design automation solution for analog and RF-IC design, and SpectreRF, a full-chip RF-IC simulator for wireless communication designs. According to AWR, this will give system-on-a-chip (SoC) designers integrated IC design and verification capabilities by combining their RF and microwave technology with Cadence's layout, simulation, and verification products.

Ted Miracco, executive vice president of AWR, noted, "The trends in the electronics industry continue to be higher levels of integration and reducing power consumption. EDA companies are trying to address these trends by providing better tools for simulating complete systems



ANSYS/Multiphysics screen. A MEMS Optical grating shows structural deformation from residual stress in materials.

that will be either integrated into mixed signal ICs or multichip modules."

Simulation software provider ANSYS also establishes strategic alliances through their Enhanced Solution Partner (ESP) program, which encourages software developers to use ANSYS as a development platform for their applications. MEMSCAP, provider of MEMS-based solutions for the design and manufacture of telecommunications products, partnered with ANSYS to develop an interface between MEMSCAP products and ANSYS/Multiphysics™, which simulates complex thermal/mechanical, fluid/structural and electrostatic/structural, and a number of coupled-physics interactions.

Software Round-Up

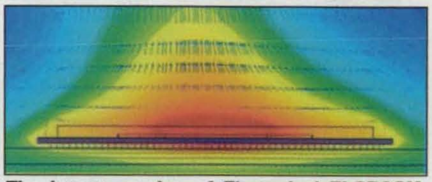
Even outside the framework of formal partner programs, innovative products offer varying degrees of interoperability and valuable design capabilities for end users.

ALGOR's Multiphysics technology, for example, operates seamlessly with most CAD solid modelers so that engineers can continue to use tools they already understand. Easy set-up enables engineers to focus on the physics of a part or assembly instead of learning the process and terminology of a specific software package. For instance, the graphical user interface allows engineers to link the results of one analysis to another by clicking on just a few options.

Bob Williams, product manager at ALGOR, commented, "Several of ALGOR's recent multiphysics enhancements are especially well-suited for the design, analysis, and optimization of electronic devices, although our FEA and Mechanical Event Simulation software are used by engineers in a wide variety of industries." Enhancements to multiphysics include the new Joule heating capability and the forced convection option. Williams noted that the Joule heating capability enables engineers to link results from electrostatic analysis and heat transfer analysis in order to calculate the heat generated by a current. Especially suitable for analyzing systems requiring fans or water for cooling, the forced convection option includes fluid convection effects in heat transfer analysis.

Jointly developed by Fluent, a provider of commercial computational fluid dynamics (CFD) software and services, and ICEM CFD Engineering, a developer of software for pre- and post-processing of engineering applications, Icepak is an object-based, thermal management and computer-aided analysis tool for electronics. Icepak can be integrated with other CAD and EDA tools thanks to enhanced CAD geometry import in IGES and DXF formats.

Companies often focus on integrating their own products rather than, or in addition to, developing interoperability with external software offerings. For instance, Electronics Workbench, a developer of Windows®-based EDA tools, recently announced the integration of three of their own products. This integration creates a seamless design environment for the schematic capture, simulation, layout/routing, and computer-aided manufacture of PCBs. The Professional and PowerPro Suites combine Electronic Workbench's Multisim (schematic capture and SPICE/VHDL/Verilog HDL/RF simulation), Ultiboard (PCB layout), and Ultiroute (autoplacement, autorouting, and manufacturing optimization) products. The PowerPro Suite differs from the Professional Suite by offering increased functionality in terms of support for programmable logic (VHDL), co-simulation, RF design, and PCBs with up to 64 layers.



The latest version of Flomerics' FLOPACK, v3.1, generates instant, ready-to-run thermal models for a range of IC packages.

Similarily, modeling software developer, Flomerics, enables parts created within their FLOPACK software, a Web-based product for thermal modeling of IC packages, to be imported directly into Flotherm, a thermal analysis software that analyzes the cooling requirements of electronic components and systems.

Electronics design is an increasingly complex discipline requiring not only engineering expertise but also specialized software. Hence, the continued success of the EDA market, which supplies these highly specialized design environments with critical tools. Since one company can rarely provide all of the tools needed for complex electronics projects, interoperability characterizes the majority of offerings in the EDA and related software markets.

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NASA Awards Inventions of the Year

NASA has chosen a Hollow Cathode Assembly and a Rotary Blood Pump as the top inventions of 2001. Researchers at Johnson Space Center in Houston, TX, received the NASA Commercial Invention of the Year for the Rotary Blood Pump Ventricular Assist Device (VAD). NASA's Government Invention of the Year Award went to a team from Glenn Research Center in Cleveland, OH, for developing both a Hollow Cathode Assembly for the International Space Station Plasma Contactor and Hollow Cathode Technology for commercial purposes. Although these innovations originated from NASA research centers, each has the ability to benefit a much wider range of industries.

Rotary Blood Pump — Ventricular Assist Device (VAD)

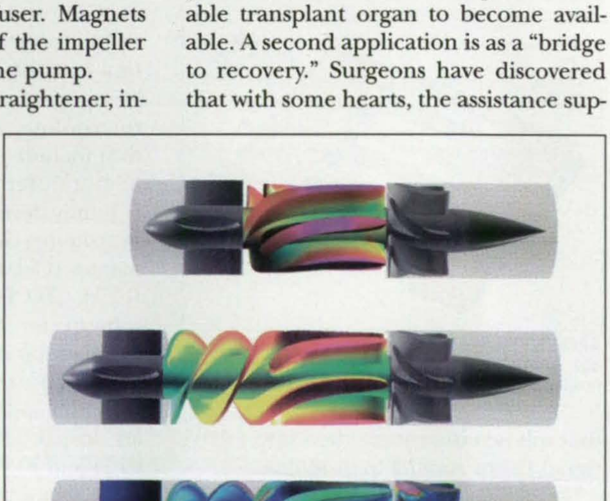
NASA's entry into blood pump technology began on a personal level. A NASA engineer suffering from congestive heart failure met with famed pioneer heart surgeon Dr. Michael DeBakey while receiving a heart transplant. As a result of their discussion, a team of NASA engineers and contractors was formed to apply the expertise gained in solving space exploration problems to benefit people with congestive heart failure. The partnership led to the development of the DeBakey Ventricular Assist Device (VAD), a small, lightweight, high-speed turbine pump that moves blood without damaging the delicate individual blood cells or allowing clotting of the blood — the two principle obstacles in blood pump technology.

The VAD includes a tubular housing that has an externally mounted motor stator, an internally fixed flow straightener within its upstream section, and a diffuser fixed within its downstream section. The only moving part — a one-piece rotor that includes an inducer portion and an impeller portion — is mounted on bearings between the flow straightener and the diffuser. Magnets embedded in the vanes of the impeller form the motor rotor of the pump.

The blades of the flow straightener, inducer, impeller, and diffuser are all optimized to function together to minimize blood hemolysis. Precisely shaped entrance and outlet angles, and the transitions between them, contribute to the overall pumping efficiency, and enhance the blood-protecting character of the design. To prevent clotting of the blood in the low-flow-rate areas around the bearings, the bearing areas are configured to allow cross-linked blood to fill and seal those areas. A back electromotive force (EMF) integrated circuit regulates rotor operation and a microcomputer may be used to control one or more back EMF integrated circuits.

The implanted device is applied externally of the heart and connected to it by cannula. It assists in the pumping of blood from the lower left ventricle of the ascending aorta rather than replacing the heart's natural pumping ability. In operation, the turbine pump is powered by batteries and has an external patient-operated controller.

The VAD is utilized in three distinct ways. Initially, it functions as a "bridge to transplant" temporary device to help the patient survive while waiting for a suitable transplant organ to become available. A second application is as a "bridge to recovery." Surgeons have discovered that with some hearts, the assistance supplied by the VAD is sufficient to allow the natural heart to repair itself, in which case the VAD can later be removed. The third anticipated application of the VAD would be as a permanent implant.



The use of NASA computational fluid dynamics (CFD) modeling capabilities led to major design improvements in the original Ventricular Assist Device (VAD), which is pictured at the top. The improved version is shown at the bottom. Adding an inducer to the DeBakey device eliminated the dangerous back-flow of blood by increasing pressure and making flow more continuous. The device is subjected to the highest pressure around the blade tips, shown in pink. (Image courtesy of NASA/Cetin Kiris)

The battery-operated pump — approximately 3 inches long, 1 inch in di-

ameter, and weighing less than four ounces — seems to be an answer to the decades-long quest to develop an implantable VAD. NASA, in keeping with its mission of transferring space-based technology to the private sector, granted exclusive rights to MicroMed Technology of Houston, TX. After extensive testing and clinical trials, the VAD became commercially available last year. This contribution will continue to be an asset to health care as more VADs are made available to more recipients, and as applications broaden to include additional uses.

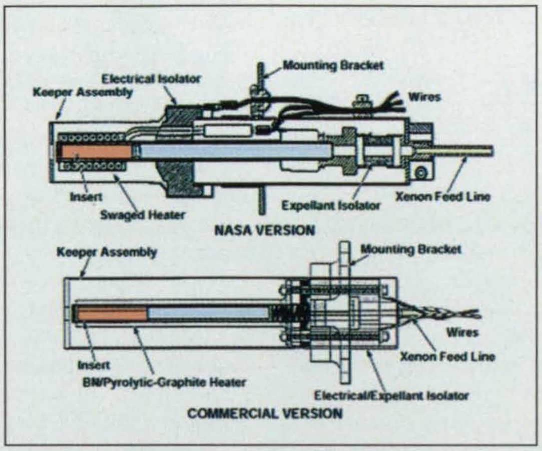
The blood pump was developed in a joint effort by Bernard J. Rosenbaum, Gregory S. Aber, Richard J. Bozeman Jr., and James W. Akkerman of Johnson Space Center; Dochan Kwak and Cetin Kiris of Ames Research Center in Moffett Field, CA; Dr. Michael DeBakey and George VanDamm of the Baylor College of Medicine; James Bacak of Lockheed-Martin; Robert Benkowski of MicroMed Technology; and Paul A. Svejkovsky of Boeing.

For more information, see the tech brief available at: www.nasatech.com/Briefs//Oct99/MSC22822.html

Hollow Cathode Assembly for the ISS Plasma Contactor

Researchers at Glenn Research Center were awarded NASA's Government Invention of the Year for developing a mission-critical, self-regulating Hollow Cathode Assembly (HCA) that controls charging on the International Space Station (ISS). The inventors also were recognized for advancing hollow cathode technology. Michael J. Patterson, Timothy R. Verhey, and George C. Soulas were able to increase hollow cathode lifetimes from about 500 hours to 28,000 hours, enabling the use of Hall and ion propulsion current for use on NASA missions, including Deep Space 1, the ISS, and STS-92.

The HCA is the primary component of the ISS Plasma Contactor System. It also mitigates spacecraft charging by emitting electron current from low-density plasma to the electrically "ground" ISS to near-space plasma potential. Early testing and prior flight experience indicated that the high voltages and exposed conducting surfaces across the ISS's solar arrays could cause the station structure to charge to a significant negative potential relative to the ambient space plasma. Since the ISS structure is electrically tied to the solar arrays, this charging could lead to arcing, damaging critical spacecraft surfaces.



The original NASA version and the commercial version of the plasma-contact hollow cathode assembly (HCA) are shown here. The commercial version preserves the technological heritage of the original NASA version, but can be mass-produced at lower cost.

The HCA alleviates spacecraft charge build-up by emitting electrons collected by the solar arrays. A discharge is ignited between the hollow cathode and anode of the HCA. The resulting plasma is coupled to the spacecraft potential. When this plasma "sees" the ambient space plasma at a different potential, electrons stream between the two plasmas to equilibrate their potentials, controlling spacecraft charging in a self-regulating manner.

The innovators developed this technology from a laboratory device to spaceflight-qualified hardware, and also manufactured the spaceflight hardware for the ISS. The hollow cathode technology developed during this program is also used for electric space propulsion — such as ion and Hall thrusters used on commercial satellites and scientific spacecraft — and plasma sources for materials processing. The hollow cathodes utilized by these devices are used either to create ions for acceleration and/or neutralize an ion beam.

Besides the successful operation on the ISS, the hollow cathode assemblies were launched aboard STS-92 and Deep Space 1. On Deep Space 1, the hollow cathodes on the ion thruster operated flawlessly for over 16,000 hours.

NASA has entered into a joint effort with Advanced Refractory Technologies of Buffalo, NY, to develop a hollow cathode for use as an electron source in the production of diamond-like coatings to replace thermionic filament cathodes. Multiple units have been manufactured and tested at NASA's Glenn Research Center and are under integration at the industrial partners' manufacturing facilities.

For more information, see the tech brief available at www.nasatech.com/Briefs//Feb00/LEW16658.html.

Seven other inventions were nominated in the 2001 competition:

- Ames Research Center developed a method and system for an automated tool for en route traffic controllers. The innovation is an optimization algorithm that predicts flight path, minimizing time between points without possible collision.
- A parallel-integrated frame synchronizer chip was manufactured at Goddard Space Flight Center in Greenbelt, MD, reducing the cost of workstations and the backlog of unprocessed science data from the Terra spacecraft. A computer-implemented empirical mode decomposition method, apparatus, and article for manufacture also were developed at Goddard, providing more efficient filtering of a signal from noise for non-linear, non-stationary data.
- Langley Research Center in Hampton, VA, developed a high-temperature polyimide resin system — an environmentally friendly alternative to a common temperature matrix resin, offering use in applications requiring a high-temperature, lightweight, high-strength material. Also developed at Langley was a method and apparatus for the portable identification of material thickness of layers using a scanning heat source and infrared detector.
- From Glenn Research Center came silicon/mullite/BSAS environmental barrier coatings, providing long-term protection from attack by water vapor and molten salts in combustion environments.
- An infector for liquid-fueled rocket engines was developed at Marshall Space Flight Center in Huntsville, AL. The invention produces low static pressure variations in the flow passages, providing uniform propellant injection.

NASA's Government and Commercial Inventions of the Year are selected by NASA's General Counsel and the Inventions and Contributions Board (ICB). For detailed information on all the winners and nominees for 2001, visit the ICB Web site at: http://icb.nasa.gov/IOY2001.

Application Briefs

E-business Platform Helps NASA Streamline Financial Management

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To streamline NASA's business processes, the agency's Integrated Financial Management (IFM) Program utilized mySAP.com®, an e-business platform designed to increase operational effectiveness. IFM is the organization aimed at improving NASA's financial, physical, and human resources management processes. The IFM Program team has conducted demonstration testing on relevant mySAP.com solutions, such as those designed for human resources, budget planning formulation, and product lifecycle management.

Recently, NASA purchased an additional 12,600 licenses for the mySAP.com suite, doubling the number of users. SAP solutions will help meet the agency's user requirements for the remaining NASA IFM Program modules — specifically, budget planning and formulation; integrated asset management including logistics, facilities, environmental and aircraft; and human resources and payroll.

"With the tightly integrated solutions of SAP, NASA will have consistent cross-agency processes, informed by best practices, that will allow us to access and assemble vital information quickly and effectively," said Mike Mann, program manager of NASA's IFM Program. A combined team of NASA and SAP employees are implementing the platform at Marshall Space Flight Center in Alabama and will extend the system to the remaining centers upon completion.

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Tensioners Hold Shuttle Arm in Place During ISS Launch

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Part of Canada's investment in the International Space Station (ISS) program is the Canadarm2, an advanced version of the shuttle's robotic arm. Unlike the original Canadarm, which is mounted just outside a shuttle's payload bay, each end of Canadarm2 has a hand that can grasp an anchor on the ISS. By flipping end-over-end between anchor points, Canadarm2 can move around the ISS like an inchworm. To install the robotic arm for use on the ISS, Superbolt Multi-Jackbolt tensioners were used on eight bolts to hold Canadarm2 in place during launch.

The tensioners are designed to replace conventional hex nuts, covered nuts, and bolts. They were chosen because they are simple to remove with hand tools and were able to achieve the bolt preloads required for the launch. This is an important consideration in keeping space-walking astronauts safe and reducing the launch weight since no heavy tooling is required.

Canadarm2 was carried to the ISS via the Space Shuttle Endeavour. Once in orbit, astronauts left the shuttle and removed the eight tensioners, allowing Candarm2 to be unfolded and positioned for installation.

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Above left to right – the DEWE-4000, DEWE-2010, and DEWE-3010 portable PC Instruments

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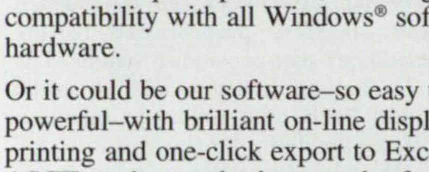

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Remote Monitoring and Alarm System

John F. Kennedy Space Center, Florida

The Remote Monitoring and Alarm System (RMAS) is a system of electronic hardware and software for monitoring of fiber-optic video transmission equipment at Kennedy Space Center (KSC). The RMAS could also monitor other equipment that generates discrete contact closures and/or analog voltages. The hardware includes multiple remote terminal units (RTUs) that are collocated with, and gather both discrete and analog information from, the monitored equipment, and convert this information to RS-232 data streams. The RTUs are connected via point-to-point long-haul modem circuits to a 96-port code-activated switch (CAS), that, in turn, connects specific RTUs to a monitoring computer workstation. Polling software running on the workstation periodically gathers data from each RTU and stores the data for processing by network-management software, which also runs on the workstation. The network-management software analyzes the data to generate a graphical representation of the fiber-optic video transmission equipment, with indications of any alarm conditions. Each RTU contains custom firmware that governs communication with the polling software and that, upon command by a user, implements diagnostic routines. A Simple Network Management Protocol agent links the polling software to the network-manager software via a custom management information base.

This work was done by Philip Gvozd, Matthew Smisor, and William Toler of **Kennedy Space Center** *and Chris Kerios, Robert Chiodini, Pamela K. Schmidt, and Robert Swindle of Dynacs, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
KSC-12314

Failure-Reporting Device Concept for Spacecraft and Remote Vehicles

Unlike aircraft "black boxes," these devices would transmit information to remote receivers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Failure-reporting devices somewhat similar to the "black box" data recorders on aircraft have been proposed. These devices were conceived for use on spacecraft, but might also be useful on terrestrial autonomous underwater vessels or terrestrial remote exploratory robots. The concept was motivated by the need to learn from mission failures in order to make future missions more failure resistant.

Even more than aircraft "black boxes," the proposed devices would be extremely rugged to survive re-entry into the atmosphere of the Earth as well as impacts substantially harder than those of airplane crashes. Unlike aircraft "black boxes," the proposed devices would not be designed to be retrieved: instead, they would be designed to transmit as much pertinent information as possible to enable analysis to identify specific causes of mission failures.

The design of the proposed devices would follow a "spacecraft within a spacecraft" approach. The device would contain data-handling, telecommunication, power-supply, and structural subsystems. The primary interfaces between this system and the spacecraft would be power connections and points of access to the spacecraft data bus and/or the spacecraft telemetry-management system. The links between the failure-reporting device and the spacecraft would be subject to severance at any time. However, even while the spacecraft remained intact and functional with the device connected, the device would transmit subcarrier beacon tones that would convey information on the status of the spacecraft during high-risk maneuvers like entry, descent, and landing.

Upon separation from the spacecraft, the device would stop drawing power from the spacecraft power supply and start drawing power from an internal battery. Once separated from the spacecraft, the device would automatically begin transmitting relevant data back to Earth ground stations and/or nearby orbiting spacecraft. A flight-qualified data processor would run the software necessary to record channelized data, set the beacon state, and execute other functions like those of an aircraft "black box." The level of data processing would depend on the degree to which the data received by the device were summarized and otherwise preprocessed by the spacecraft data-processing system. The most important data would be stored (most likely in a solid-state memory) aboard the device for transmission.

The telecommunications and software subsystem of the device would generate low-rate telemetry signals to transmit stored engineering data. If possible within the processing constraints, summarization software would transmit the most relevant sensor data recorded around the time of the failure. The subcarrier signals could be programmed to correspond to spacecraft failure modes and would provide some indication of status in the event that acquisition of telemetry was not possible.

This work was done by E. Jay Wyatt and John Szijjarto of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
NPO-20942

Program Uses Terrain-Image Data To Locate Safe Landing Site

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program under continuing development strives to locate a safe landing site for a spacecraft through real-time processing of image data acquired by a video camera aimed at the terrain below while the spacecraft descends. The program might also be useful for aiding the selection of a landing site for an unpiloted helicopter or other unpiloted aircraft capable of slow vertical or nearly vertical descent. The program implements two main algorithms: a texture-based landing-site-selection algorithm and a landing-site slope-estimation algorithm. The texture-based algorithm analyzes spatial variations in image brightness to identify candidate sites that are acceptably smooth and free of large rocks. The slope-estimation algorithm computes the slope on the basis of the perspective relationships between two images of the same terrain area acquired from successive positions along the descent trajectory. Because the slope is a very important factor for safe landing and for mobility of a robotic exploratory ground vehicle to be deployed from the spacecraft after landing, the slope-estimation algorithm includes an error-analysis subalgorithm.

This program was written by Yang Cheng, Andrew Johnson, Larry Matthies, and Aron Wolf of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30268.

Measuring Sea Height and Roughness With GPS Reflections

Dense and rapid coverage would enable new oceanographic applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed technique of bistatic radar altimetry would utilize information available in Global Positioning System (GPS) signals reflected from the ocean surface. The signals would be monitored by an airborne or spaceborne receiver and would be processed to determine the height, roughness, and possibly other properties of the surface. An important advantage of the proposed technique would be density and rapidity of coverage: Whereas a traditional nadir-looking radar altimeter gives the surface height at only one location below the altimeter, a receiver implementing the proposed technique could track about 10 GPS reflections simultaneously. Such dense coverage could translate to spatial and temporal resolutions greater than those previously achievable, and hence the ability to study ocean-topography features or processes beyond the reach of prior techniques. Potential applications could include monitoring of

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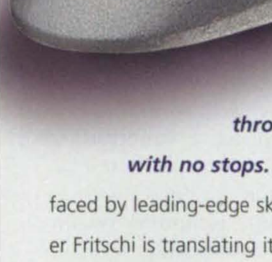

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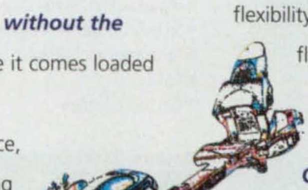

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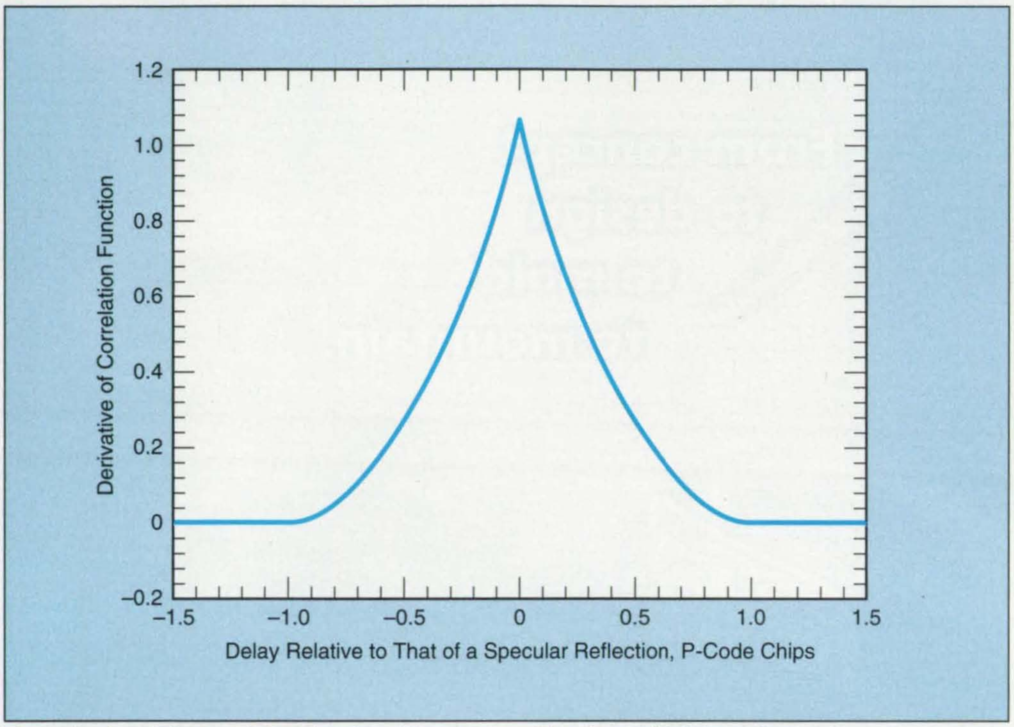
eddies and tides and tracking of fast barotropic waves.

The proposed technique is an extended version of the cross-correlation process used to extract time and position information from direct GPS signals. The extension to the reflected-signal case involves consideration of numerous factors, including the field of view and pointing direction of the receiving antenna, the angle of scattering of each affected GPS signal, the direction of the plane of incidence of the GPS signal relative to the velocity of the spacecraft or aircraft carrying the receiver, and the integration time of the receiver.



The **Derivative of the Correlation Function** with respect to delay time yields information on three sea-state parameters, as described in the text. The unit of delay time is one repetition period ("chip") of the GPS pseudonoise code — a period ≈0.1 second.

One function of particular importance for the mathematical foundation of the technique is the derivative of the correlation function (DCF) with respect to the model time delay. This function exhibits a sharp peak (see figure), the shape of which is affected in known ways by the wind speed and by surface-roughness statistics. Hence, in principle, one should be able to extract important sea-state parameters from the DCF. These parameters are, specifically, (1) the mean sea height (derived from knowledge of the location of the DCF peak relative to the model delay), (2) the ocean-surface wind (derived from the height of the DCF peak), and (3) the significant wave height (derived from the width of the DCF).

The effects of the ionosphere, troposphere, and clock errors on the accuracy of the technique have been estimated, and an overall root-mean-square value of range accuracy has been predicted as a function of sea state and antenna gain. It has been found that when one averages many measurements collected from a possible constellation of receivers, the range error would be progressively reduced as a function of space and time, yielding predicted accuracies in estimated sea height with associated spatial and temporal resolutions. Preliminary calculations indicate that sea-height accuracies of a few cm on spatial scales of 100 km from measurements averaged over four days could be achievable.

The effect of wind speed and significant wave height on the received signal has been examined by computational simulation for realistic ranges of wind speeds and wave heights. The bistatic geometry has been found to make the sea-height measurements less sensitive to wave heights than are the sea-height measurements of conventional nadir-

viewing geometry. The electromagnetic bias of the scattered waveform has also been found to be reduced. The range accuracy versus receiving-antenna gain and scattering direction were also examined; it was found that at low elevation angles, both the scattering cross section and the coherence time are greater than those at nadir, resulting in a potential decrease of the range error for a fixed antenna gain. Finally, the possibility of tracking the phase of the GPS signal at small elevation angles and the resulting improvement in the range-measurement accuracy has also been examined theoretically.

This work was done by Cinzia Zuffada, George Hajj, and J. Brooks Thomas of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*
NPO-20943

Hybrid Electric-Field Sensor

John F. Kennedy Space Center, Florida

The hybrid electric-field sensor (HEFS) has been proposed for measuring quasi-static electric fields — especially those associated with thunderstorms. The HEFS would combine the relative compactness, low cost, and low power consumption of prior induction-probe-type electric-field sensors with the higher sensitivity of the prior field-mill-type electric-field sensors. The HEFS design would utilize a chopping-electrostatic-shield feature of a field mill over two insulated antennas to overcome the finite time constant and the poor upper frequency response of the induction probe and the electric field mill, respectively. The HEFS would be modular in order to accommodate "smart" data-acquisition and communication ports for operation as a battery-powered, stand-alone unit. Optionally, the HEFS could incorporate a barometer, thermometer, and hygrometer, so that it could serve as a portable meteorological station. A network of such stations could transmit digitized measurement data to a central monitoring station. The estimated cost of an HEFS, including communication circuitry, is $1,000 (based on prices as of year 2001). In contrast, a field mill costs about $10,000. Moreover, unlike a field mill, an HEFS would consume little enough power that it could be powered by a solar power system backed by rechargeable batteries.

This work was done by Carlos T. Mata of Dynacs, Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
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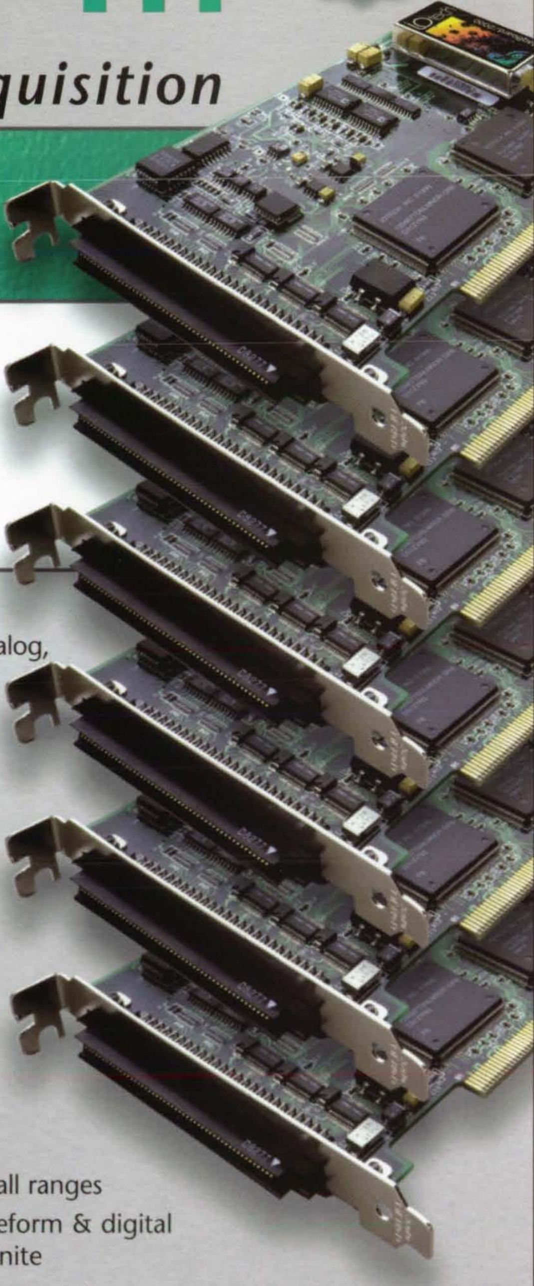

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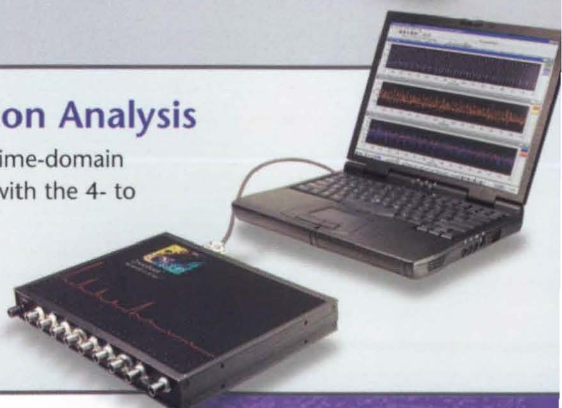

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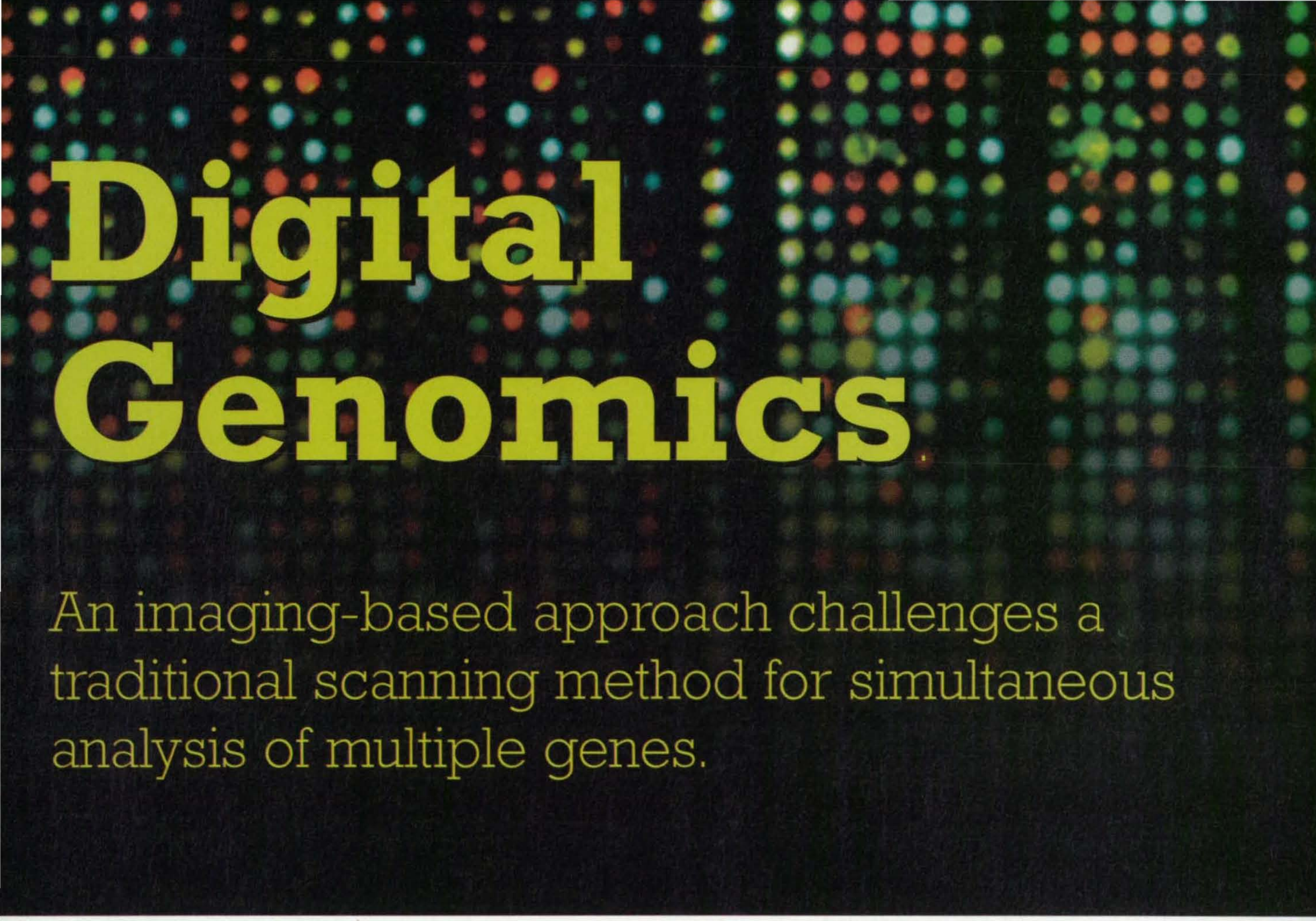


Digital Genomics

An imaging-based approach challenges a traditional scanning method for simultaneous analysis of multiple genes.

Traditional biology has centered on the study of a single gene, that is, the attempt to identify all the factors that regulate the activity level of a particular gene. This approach has been painstakingly slow, but very rewarding in terms of obtaining specific information about the gene being studied. With the announcement that the entire sequence of the human genome has been identified, the rush is on to utilize the vast amount of information now available.

There are an estimated 80,000 to 100,000 unique genes encoded within the human genome and in order to determine the various functions of all of these genes, scientists are actively developing methods to analyze many of them in parallel. This tack makes numerous new and interesting experiments possible, like identifying all the genes that are changed in response to a biologically active molecule such as a hormone or a drug.

While much of the early work in this area has relied on data-collection methods that employ serial scanning, new protocols based on digital imaging are now proving highly successful. Recent advances in electronics technology and new methods of high-volume manufacturing are making it possible for builders of microarray scanners to affordably integrate advanced CCD imagers as components in their systems. On a smaller scale, it is even possible for individual researchers to use currently available camera systems for microarray imaging experiments in their own laboratories.

Measurement of Gene Activity

In order to measure a gene's activity, scientists collect the messenger RNA (mRNA), which carries information from the gene in the nucleus to the cytoplasm, where it is usually translated into a protein product. When the RNA from a cell population or tissue is collected, this preparation is typically converted into copy DNA (cDNA) and then amplified with the polymerase chain reaction (PCR). A sample of the amplified cDNA product can be labeled with fluorescent tags to allow that population to be identified.

Typically, the researcher uses two populations of cells: one representing the control and one representing the experimental treatment. As an example, a cultured cell line's response to insulin can be measured by preparing two cell populations: one treated with insulin and one mock treated. The RNA from the insulin-treated cells can be labeled with Fluor 1 (green color) and the RNA from the control cells can be labeled with Fluor 2 (red color). These probes can then be used to interrogate a microarray of immobilized DNA targets on a glass surface, where each (x,y) coordinate represents a known DNA sequence.

When the green and red probes are hybridized to the array, the composite color is a measure of the gene activity ratio. A green color would indicate a gene that is on with insulin treatment and off when insulin is absent. A red color would indicate a gene that is on when insulin is absent and off with insulin treatment. A yellow color would indicate a gene that does not change significantly with insulin treatment.

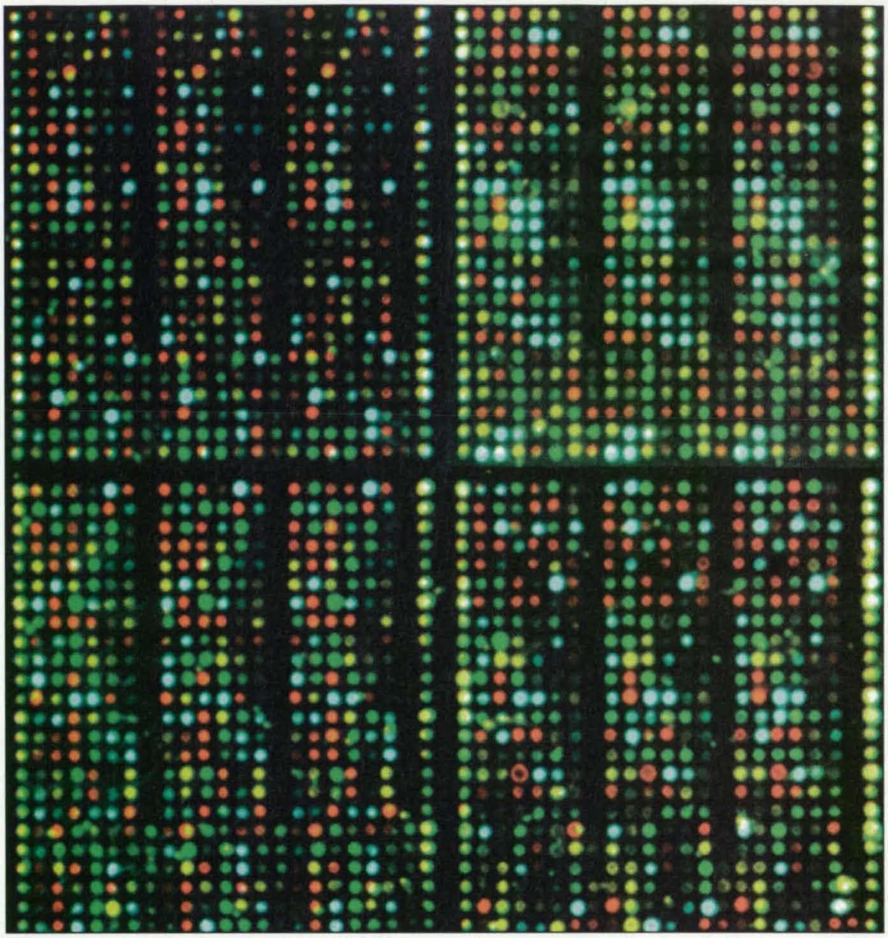
Basic Analytical Approaches

Once the arrays have been hybridized and washed under the appropriate stringency conditions, the user needs to read the arrays at two different wavelengths of interest. The wavelengths used are usually in the red region of the spectrum to reduce auto-fluorescence from the system. The most commonly used labels for

microarray experiments are Cy3 and Cy5, depicted as green and red, respectively. Two basic approaches can be utilized to measure these signals: serial scanning or imaging.

In the serial scanning approach, a confocal fluorescent scanning device collects data serially using a common optical pathway for delivering the excitation beam and for collecting the emission beam. The fluorescent signal is measured by a photomultiplier tube and digitized to generate the output intensity at each spot on the microarray. After the first fluorescent channel has been measured, the optics are switched and the second channel is then measured.

In the imaging approach, a wide-field illumination scheme is utilized to achieve parallel excitation on most or all of the microarray. Similarly, the imaging of the whole array then occurs in parallel with an exposure time chosen to obtain the best signal-to-noise in the data. A camera digitizes the data and all of the digital data is delivered to the computer in an image format. For the second wavelength, the optics will need to be changed and another exposure taken.



Microarray image showing typical differences in gene expression levels. Image courtesy of Roper Scientific, Inc.

Scanning Vs. Imaging

So which is the better method for analyzing this kind of data? Right now, the majority of the microarray scanners on the market employ the serial scanning approach. This is due to the simplicity of design of a system that uses a laser for illumination coupled with a PMT for a detector. In terms of performance, however, there are distinct advantages to moving to an imaging-based approach.

For example, in selecting laser lines for illumination in serial scanners, the fluorescent probes become confined to those whose excitation spectrum is sufficiently overlapped with the laser line to be useful. In the imaging approach, broadband emitters like xenon (Xe) or mercury (Hg) can be used to generate an almost continuous usable spectrum of illumination light.

Furthermore, by using a CCD-type detector to measure the fluorescence signals, an imaging device can achieve quantum efficiencies on the order of 90% — versus the 15-20% QE obtainable with a PMT-type device. This difference translates into a sensitivity advantage of up to sixfold! The CCDs can also be run with very low-noise analog electronics to achieve a readout noise lower than 4 e^- rms, whereas the PMTs can have noise terms that are significantly higher.

Another key advantage of the imaging-based approach is the highly parallel nature of the data collection. If the user needs to collect 5,000 data points in one experiment and 20,000 in another, the scanning approach will require four times longer for the second experiment than the first. In an optimized imaging experiment, both measurements will be under identical exposure conditions and so the time will be equal. As the number of elements in an array increases, the advantage of imaging over serial scanning becomes more pronounced.

Conversely, one of the arguments in favor of serial scanners over imaging devices is the former's ability to achieve a larger number of effective pixels. This ability is useful for the currently accepted standard of measuring each 100-micron DNA spot with a 10 × 10-pixel array, a practice that yields 70-80 (on average) individual valid measurements within the circular spot. The rationale for obtaining this highly oversampled data is that it enables the interpreting software to derive detailed statistics on the variation from spot to spot as well as to use this information to qualify the quality of the data in the spot. While this method does indeed give the software a good idea of the uniformity of the distribution of the signal across the spot, it really does not address the core issue of whether or not the data is useful or quantitative.

In all biology, the standard manner to ensure the usefulness or validity of the data is the replicate method. Every biochemical assay is done in at least triplicate. Every plate-based assay is done in at least duplicate. The variation across replicates or triplicates is defined by the coefficient of variation; this number places a boundary on the usefulness of the data. The same principle should be applied in the microarray field, that is, all spots should be represented at least twice on each microarray and these spots should not be in the same region of the array. This approach eliminates the need for the high level of oversampling employed with serial scanning. Under these conditions, the finite number of pixels on the CCD is no longer a limiting factor.

This article was written by Mark Christenson, Ph.D., Senior Scientist, and Jeff Grant, Senior Technical Writer, at Roper Scientific, Inc. The authors can be reached at mchristenson@roperscientific.com and jgrant@roperscientific.com. Learn more about Roper Scientific at www.roperscientific.com.

Product Guide: Raman Spectrometers

Utilized in a variety of industries and applications, Raman spectroscopy is a technique that continues to gain in popularity. The evolution of enabling technologies such as laser diodes and detectors combined with minimal need for sample preparation has contributed to this acceptance.

By shining a laser on a sample and detecting the scattered light, Raman spectrometers allow for qualitative and quantitative analysis of materials. Applications exist in semiconductor, pharmaceutical, quality control, and research industries, for example.

Raman spectroscopy is complementary to infrared absorption spectroscopy — some instruments even combine the two functions into one device. It also offers advantages. Raman analysis allows measurements to be made through transparent structures such as glass vials or by using fiber-optic probes. Raman also simplifies the analysis of aqueous samples by eliminating the need for special preparation and accessories.

Arranged alphabetically by company, the featured products are representative of available offerings and may not include all of the Raman technologies manufactured by each company. Additional information should be obtained directly from the manufacturer.

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Raman Range: 150 cm^{-1} - 3,500 cm^{-1}
Laser: 1,064 nm YAG laser
Detector: MIR-NIR DTGS/FT-Raman
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Laser: diode-pumped Nd:YAG
Detector: InGaAs or Ge
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FRA 106/S: Dual IR-Raman

The components used in the FRA106/S are identical to those in the RFS 100/S (see previous listing). This FT-Raman module is suitable for users requiring both IR and Raman capabilities. The FRA 106/S can be attached to several of Bruker's FT-IR spectrometers providing a FT-IR/FT-Raman solution.

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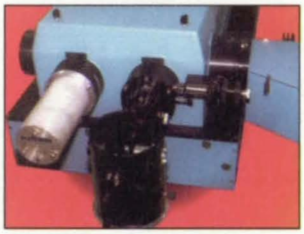
207/275DS: Raman System



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R-2001: Integrated Raman

Spectral Range: ~200-2,700 cm^{-1}
Laser: 500 mW, solid state 785 nm diode laser
Detector: CCD
Features: This all-in-one system delivers detailed spectral analysis of aqueous solutions, gels, powders, coatings, and surface media. The R-2001 series of spectrometers include a CCD-array spectrometer, an analog-to-digital converter, and 32-bit Windows operating software. The R-2001-G25 has a spectral range of ~200-4,000 cm^{-1} and a 25mW, solid state 532 nm diode laser source. The R-2001-G50 has a spectral range of ~200-4,000 cm^{-1} and a 50mW, solid state 532 nm diode laser source.

RSL-1: Portable Raman

Weight: 15 lbs.
The RSL-1 includes the standard Raman System components, as well as a probe or sample chamber, embedded computer, power supply, and optional customized, factory-installed calibration library. The unit provides users with a complete at-site Raman analyzer for chemical and pharmaceutical analysis.

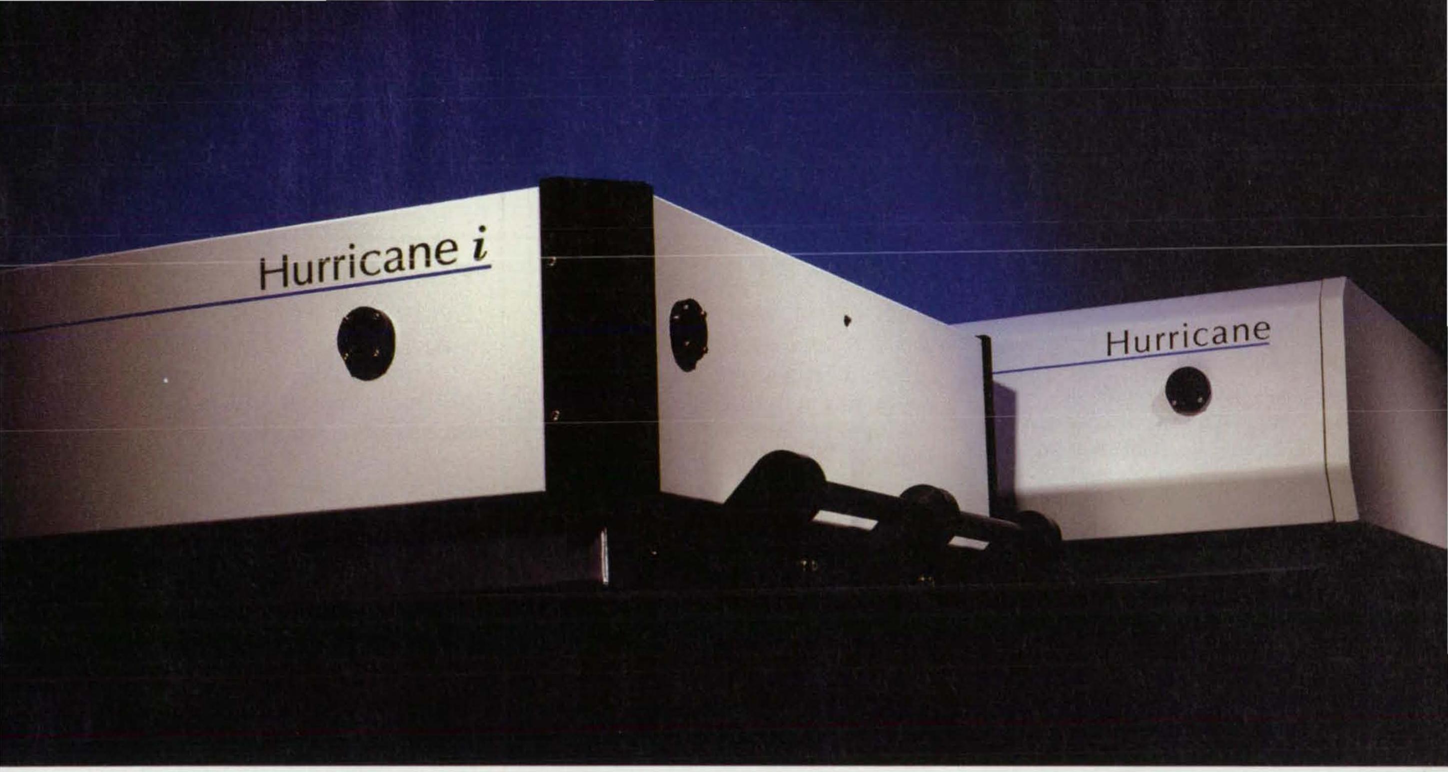
THERMO NICOLET
Waltham, MA
www.thermonicolet.com

FT- Raman 960

Spectral Range: 3,600-100 cm^{-1} Stokes, 300-2,000 anti-Stokes
Spectral Resolution: better than 0.8 cm^{-1}
Laser Source: Nd: YVO_4 1.064 µm
Detector: Ge or InGaAs
Features: This dedicated system for optimized FT-Raman spectroscopy features gold-coated optics, an external laser option, and a dynamically aligned, frictionless flex-bearing interferometer with CaF_2 beam splitter. OMNIC® software and Raman spectral libraries included.

Almega™ Dispersive Raman

Spectral Range: 400 - 1,050 nm
Spectral Resolution: 2 cm^{-1}
Laser Source: 785, 633, or 532 nm
Dimensions: 58 x 72 x 58 cm, 295 lbs.
Features: This Raman spectrometer integrates microscopy and a full-size sample compartment into a single, enclosed automated system. OMNIC® software and Raman spectral libraries provide an integrated, Windows® compatible interface for system control and data analysis. Sampling applications include semiconductor, pharmaceuticals and polymers.


Hurricane i
Hurricane

Technologies of the Month

Sponsored by yet2.com

For more information on these and other new, licensable inventions, visit www.nasatech.com/techsearch

Reactive Pulse Shaper for Inductive Transmitters

Robert Bosch GmbH

Schmitt-triggers provide a means of processing an alternating voltage into rectangular current pulses, which can then be counted; however, the stable hysteresis of the Schmitt-trigger (i.e. it is either "on" or "off") reduces sensitivity to interferences that extend beyond its hysteresis threshold. This causes the generation of erroneous pulses and consequently errors in measurement.

Robert Bosch GmbH's reactive pulse shaper — a Schmitt-trigger and a peak value detector connected to the output of an inductive transmitter — overcomes this limitation by defining the threshold of the Schmitt-trigger with respect to the peak value thereby reducing sensitivity to spurious interference, which enhances the accuracy of the inductive transmitter.

This device has been fully developed and has been incorporated in automotive engine management systems. Other applications may require further development. Applications and potential advantages exist for shaft angle measurement in gas turbines, valve control in rotary and reciprocating pumps, and precise control of drives in rolling mills.

For more information go to:
www.nasatech.com/techsearch/tow/pulse.html
email: nasatech@yet2.com;
phone:617-557-3837

Fiber-Optic Security System Technology

Based on Optical Fiber Speckle Pattern recognition, this security system technology employs optical fibers, which are thin, light, flexible and immune to electromagnetic interference, as sensors. The system is based on the transmission of a laser beam in a fiber-optic cable. Any movement of the cable can be adjusted to set-off the alarm. The signal-to-noise ratio can be adjusted to remove undesired types of alarm triggers (i.e. external vibration caused by wind, rain, and small animals).

This security monitoring system technology is especially suitable for controlling large and long components such as country borders. When applied under road cable, it can be used to monitor traffic count.

For more information go to:
www.nasatech.com/techsearch/tow/security.html
email: nasatech@yet2.com;
phone:617-557-3837

Iron-Base, Wear-Resistant Alloys

NOREM is an alloy that protects critical components from wear and corrosion damage in challenging environments. NOREM products and deposition procedures — using various conventional joining techniques — have been developed to facilitate coating operations. For example, NOREM can be welded onto a number of carbon and stainless steel substrates with little or no preheating.

Specifications for various NOREM products (powder, rod, wire, and strip) have been developed. Procedures for applying the alloy using conventional welding techniques (plasma transferred arc welding, gas tungsten arc welding, gas metal arc welding, and shielded metal arc welding) are also available. NOREM has already been used as a hardfacing alloy in new or replacement valves for nuclear power plants in the field to perform in situ repair of valves.

For more information go to:
www.nasatech.com/techsearch/tow/alloys.html
email: nasatech@yet2.com;
phone:617-557-3837

Microcavity Device for Measuring Direction of a Laser Beacon

Angular resolution could be as fine as tens of nanoradians.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optoelectronic device based on interferometry in a resonant microcavity has been proposed for use in measuring the direction of arrival of a circularly polarized beam of light from a beacon laser. In comparison with prior optoelectronic direction sensors, the proposed device would be simple, compact, and lightweight, in that it would contain no moving parts and no imaging optics and could be fabricated from semiconductor crystals. Moreover, it should be possible to integrate readout electronic circuits directly onto the device; these circuits would perform all needed intermediate signal processing to generate electrical output indicative of the angle of incidence of the laser beam on the device. In one potential application, the beacon would be located at one end of a free-space optical-communication link and would be used as a target for aiming a transmitting telescope located at the other end of the link. In another potential application, the beacon could be used similarly as a target for measuring angles precisely in land surveying.

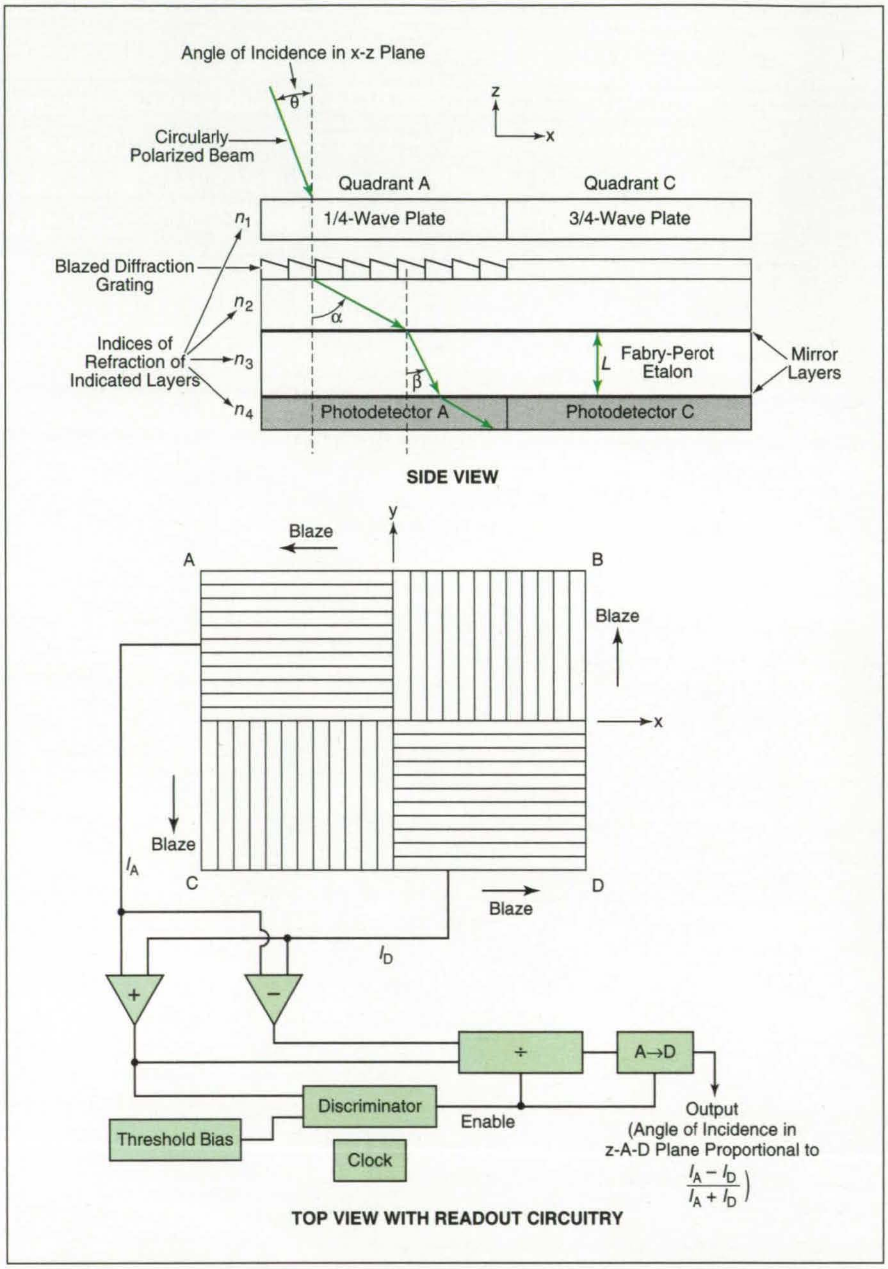
The device, denoted an optical pointer on a chip (OPOC), would be divided into four quadrants, each of which would contain a wave plate in series with a blazed transmission-type diffraction grating, a Fabry-Perot etalon serving as a resonator, and a photodetector (see figure). Each wave plate would transform the circular polarization of the laser beam into the linear polarization optimum for the blaze of the grating in its quadrant. A complete explanation of the principle of operation would entail a great deal of mathematical derivation and, as such, would greatly exceed the space available for this article. In summary:

- The device would exploit the sharp dependence of the transmissivity of a Fabry-Perot resonator on the internal angle (β) of refraction or diffraction.
- The spatial period of the diffraction grating would be chosen so that normally incident light would be diffracted to a desired order inside the resonator at a desired angle β.
- The blazes in the opposite quadrants of the grating would oppose each other in such a manner as to select opposite diffraction orders (e.g., the $+j$th and the $-j$th) in opposite quadrants.
- The net result of the aforementioned features is that the currents generated in the photodetectors in opposite quadrants would respond antisymmetrically to a deviation of the laser beam from normal incidence. To a first-order approximation for an angle that is a small fraction of a radian, the angle of incidence in a plane containing the outer corners of quadrants A and D would be proportional to

$$(I_A - I_D)/(I_A + I_D),$$

where I_A and I_D are the photodetector currents for quadrants A and D, respectively. Similarly, the angle of incidence in the plane containing the corners of quadrants B and C would be proportional to

$$(I_B - I_C)/(I_B + I_C).$$



This **Optical Pointer on a Chip** would contain several well-known optical components in a unique combination such that the currents generated in the photodetectors in opposite quadrants would respond antisymmetrically to a deviation of the laser beam from normal incidence.

Several design parameters [e.g., the thickness of the Fabry-Perot etalon, β, the reflectivity (preferably close to 1) of the mirror layers on the etalon, the laser wavelength, the indices of refraction of the device materials] affect the factor of proportionality and other aspects of the angular response of the device. It has been estimated that resolution of the order of tens

of nanoradians could be obtained by suitable choice of design parameters and execution of design by mass-production techniques now in use in the semiconductor industry.

This work was done by John Sandusky of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to Intellectual Property group, JPL, Mail Stop 202-233, 4800 Oak Grove Drive, Pasadena, CA 91109, (818) 354-2240. Refer to NPO-21117, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fabricating Sapphire Optical Fibers for High-Temperature Use

Polycrystalline cladding layers are formed on sapphire cores.

John H. Glenn Research Center, Cleveland, Ohio

A process for the fabrication of coated sapphire multimode optical fibers has been developed. Sapphire multimode optical fibers are suitable for use as embedded sensors for measuring mechanical and thermal stresses and strains in material specimens at temperatures up to about 1,500 °C.

The core of each optical fiber of this type is made of optical-grade single-crystal sapphire (which is basically an allotrope of alumina). The sapphire core is clad with a layer that has an index of refraction smaller than that of sapphire, in order to confine propagating optical signals predominantly in the core and limit attenuation at the surface of the core. The cladding material preferred for thermal durability and for chemical compatibility with the core is polycrystalline alumina; however, one or more other optical materials (e.g., SiO_2, MgO, $Al_xSi_yO_z$) could be used for cladding. The cladding should be at least a few tens of microns thick, the exact required thickness depending on the optical properties needed for a specific application. The cladding is coated with an outer protective layer of SiC, ZrO_2, Ta_2O_5, HfO_2, or other strong, high-temperature-resistant material.

The techniques used to apply the cladding and protective layers are critical to the success of the fabrication process. The techniques and the fabrication sequence are chosen to ensure adhesion between adjacent layers. Although the process admits of a number of variations, the following steps are typical:

1. The surface of a sapphire optical fiber is prepared by cleaning in hydrochloric acid followed by rinsing in distilled water.
2. Alumina particles no larger than about 20 nm are suspended in a suitable monomer (e.g., acrylic acid) and a suitable accelerator and initiator are added to the suspension.
3. The fiber is immersed in the suspension for about half an hour to allow a thin sublayer of polymer and alumina particles to begin to form on its surface, and the fiber is allowed to stand out of the suspension for another 24 hours, during which time the monomer polymerizes. All of the foregoing steps take place at room temperature.
4. The coated fiber is heated to a temperature of 600 °C to remove the polymeric binder, leaving the alumina particles in place.
5. The coated fiber is heated further to a temperature between 1,300 and 1,500 °C for a time between 10 and 60 minutes, in order to sinter the alumina particles around the sapphire core. The precise temperature-vs.-time sintering schedule is chosen to suit the intended application.
6. Steps 2 through 5 are repeated, as needed, in order to accumulate cladding sublayers to the required cladding-layer thickness.
7. A suspension of particles of the protective material is prepared as in step 2, then applied to the fiber and consolidated as in steps 3 through 5.

This work was done by Don J. Roth of **Glenn Research Center** *and Mahmoud A. El-Sherif, Ihab L. Kamel, and Frank K. Ko of Drexel University. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17054.

Etching Mirror Facets on SOI Optical Waveguides

Surfaces of high optical quality could be mass-produced.

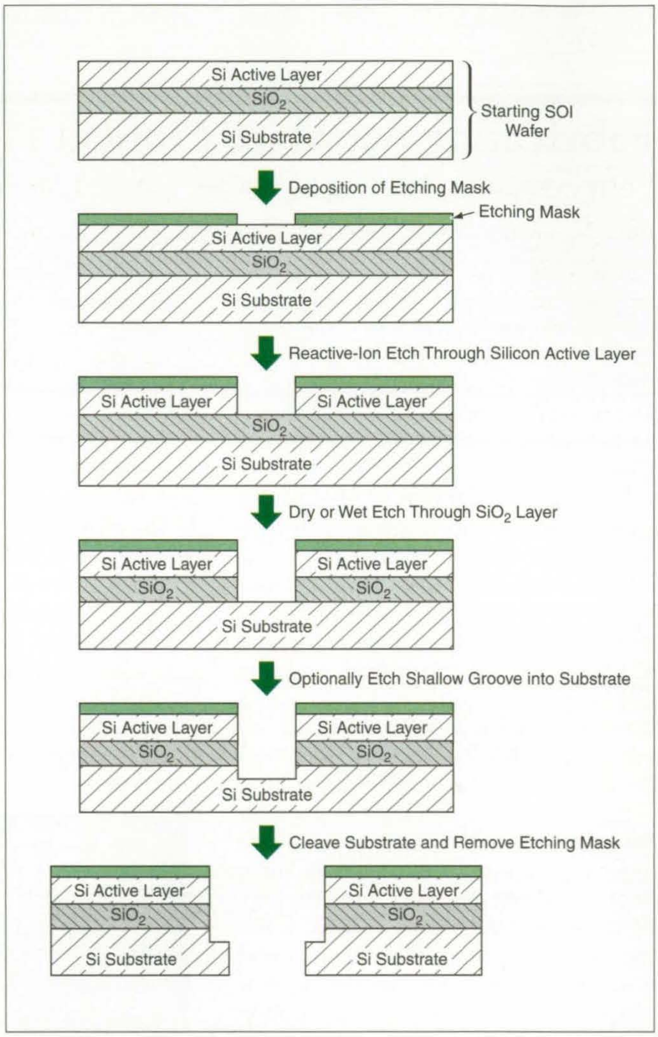
NASA's Jet Propulsion Laboratory, Pasadena, California

A process that would include a combination of dry and wet chemical etching has been proposed for making facets for low-loss mirrors on silicon-on-insulator (SOI) optical waveguides. Heretofore, such facets have been made by a process that includes dicing and polishing. This process is time-consuming and thus not suitable for mass production; moreover, the optical quality of the facets is limited by the size of the powder grains used in polishing. (Although it is possible to make nearly optically perfect facets by cleaving, the yield achieved in practice is too low for mass production.)

The etching techniques in the proposed process are already used for mass production in the semiconductor and integrated-circuit industries, and are expected to yield facets with optical quality superior to that achievable by polishing. There are two versions of the proposed process. The main steps of the first version (see figure) are the following:

1. Deposit an etching mask on top of the silicon active layer.
2. Do a reactive-ion etch through the thickness of the silicon layer.
3. Do either a dry etch or a wet chemical etch through the thickness of the SiO_2 layer.
4. Optionally, etch a shallow groove into the silicon substrate.
5. Cleave the silicon substrate. A high yield can be obtained if one cleaves via an etched groove.
6. Remove the etching mask.

The main steps of the second version of the proposed process are nearly identical, except that one would turn the wafer upside-down and etch through the substrate first. The advantage of the second approach is that one would generate the facets by cleaving the silicon active layer; the quality of the facets would therefore be better than that achievable (by etching) in the first version.



Facets of High Optical Quality would be formed on the etched surfaces of the silicon active layer.

This work was done by Chi Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Manufacturing category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20757, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Array of Switches for Fiber-Optic Communications

Optical losses would be reduced, relative to prior switches.

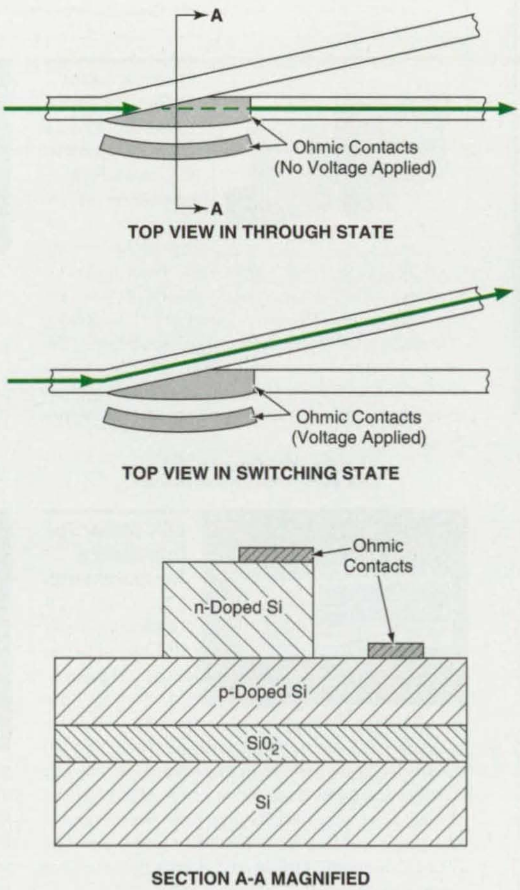
NASA's Jet Propulsion Laboratory, Pasadena, California

A rectangular array of Y-junction electro-optical switches has been proposed as a prototype of reliable, high-speed cross-point switches for fiber-optic-based photonic communication systems. The proposed array would feature a hybrid digital/interference design. The proposed array would be an integrated-optics device, fabricated in the silicon-on-insulator material system; it would be compatible with silicon-based electronic integrated circuits and with up-to-date V-groove packaging.

Some previously developed electro-optical switches are said to be of the interference (more precisely, two-mode interference/single-mode propagation) type, for which the switching characteristic is sinusoidal. The performances of interference-type switches are sensitive to (and can thus be degraded by) imperfections of fabrication and variations of polarization, wavelength, operating voltage, and temperature. Hence, it is difficult to make a high-performance large interference-type switching array.

Some other previously developed electro-optical switches are said to be of the digital type. One subtype includes InP- and GaAs-based symmetric-Y-junction waveguide switches. In the case of an InP switch of this subtype, there are two electrodes on each of the two arms of the Y. When no current is made to flow through the electrodes, the switch behaves as a 3-dB power splitter. When sufficient electrical current is injected via the electrodes on one waveguide arm, the index of refraction of that arm decreases by enough that light no longer enters that arm and instead goes entirely into the other arm. Because each waveguide arm is designed to support propagation in only one mode, the light transmission versus the applied current exhibits a step-function characteristic; that is why a switch of this type is denoted a digital optical switch. When the current is turned on, there is an optical loss because (1) the reflection wall is tilted because of spreading of the injected current and (2) imperfections of the tips of the Y give rise to radiation and scattering.

The proposed array would contain ridge-waveguide structures. The waveguide ridges would be made of silicon, and the upper and lower cladding (optical-confinement) layers would be made of air and silicon dioxide, respectively. Very low optical-propagation loss has been achieved in such a structure; this is attributable to low optical loss in the air and SiO_2 layers. The silicon wave-guiding layer in the proposed array could be designed with low doping concentration for low optical absorption.



This **Electro-Optical Switch** (one of many in a rectangular array) would divert light to the branch waveguide when a sufficient current was injected via the electrodes.

The principle of operation of the switches in the proposed array would differ from the principles of operation of previously developed electro-optical switches. A switch in this array would exhibit two states — denoted "through" and "switching." These states are defined in the figure. The through state would involve multimode interference (instead of single-mode propagation). The principle of operation and the design to implement it would significantly reduce (in comparison with an InP switch as described above) the optical loss in through state, while retaining the step-function switching characteristic essential for effectively digital switching.

The throughput-waveguide portion of each switch would be curved; the precise shape would be chosen to minimize the throughput loss. The electrodes for each switch would be formed in a lateral acceptor-doped/intrinsic/donor-doped [positive/intrinsic/negative (PIN)] configuration that would suppress spreading of the injected current into the branch waveguide; as a result, the optical loss that would otherwise be associated with current spreading in the switching state could be minimized.

This work was done by Chi Wu and Simiak Forouhar of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Pasadena, CA 91109
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E-mail: ipgroup@jpl.nasa.gov

Refer to NPO-20755, volume and number of this NASA Tech Briefs *issue, and the page number.*

New Products

Product of the Month

Multi-Sensor Metrology System

Optical Gaging Products Inc.'s (Rochester, NY) SmartScope® Quest 250 is a benchtop, multi-sensor dimensional measurement system with TeleStar® optics. As a multi-sensor system, SmartScope Quest integrates data from video, touch probe, and laser sensors to completely characterize a part. Parts that previously needed to be measured in separate set-ups on different machines can be measured entirely with SmartScope Quest. Software options dovetail smoothly into the company's MeasureMind® 3D Multi-Sensor metrology software, offering CAD import, contour analysis and fitting, and customized report generation and data export. Applications exist in virtually any industry that manufactures parts needing accurate dimensional inspection and measurement.

For Free Info Circle No. 730 or Visit www.nasatech.com/OpticalG

Excimer Laser Series for FBGs

Lambda Physik (Fort Lauderdale, FL) introduces a new series of excimer lasers designed for writing fiber Bragg gratings. The FBG laser series is equipped with dedicated resonators and deliver very high coherence. The series offers four UV sources, differentiated by their throughput capabilities. The series — consisting of the L1FBG®, FIBEX™, COMPex FBG™, and OPTex FBG™ — can manage applications requiring high throughput production or single gratings for R&D.

For Free Info Circle No. 731 or Visit www.nasatech.com/Lambda

Space Saving Pressure Transducer

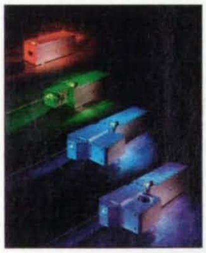
Setra Systems' (Boxborough, MA) Model 227 pressure transducer weighs 6.5 oz., stands 3.6" high, and features a space saving 1.125" Down-Mount "C" Seal interfacing base. The transducer is designed for installation on modular gas delivery systems or panels for monitoring of specialty gas processes in high purity gas delivery systems and semiconductor process tools. The Model 227 is available with 5 VDC, 10 VDC or 4 to 20mA output with 0.25% of full-scale or 1.0% of reading accuracy.

For Free Info Circle No. 732 or Visit www.nasatech.com/Setra

LCR Meter for Impedance Measurements

The 1730 LCR Digibridge meter by QuadTech, Inc. (Maynard, MA) was designed for fast throughput of component evaluation in a high volume production environment. The 1730 features measurement of 12 impedance parameters, 0.1% accuracy, test frequencies to 100 kHz, high resolution LCD graphical display, plus monitoring of AC voltage and current to the device under test. The 1730 will measure, display, and output the results of any two parameters.

For Free Info Circle No. 733 or Visit www.nasatech.com/QuadT



Diode-Pumped Solid-State Laser

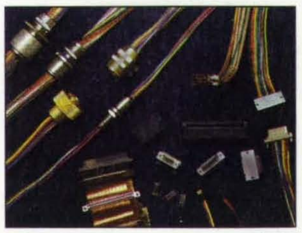
The HIPPO (High Intensity Peak Power Oscillator) from Spectra-Physics (Mountain View, CA) is an industrial, diode-pumped solid-state laser optimized for micromachining of metals, semiconductors, and polymer materials. Available with output at 1064 nm, frequency doubled to 532 nm (>11 W), and frequency tripled to 355 nm (>4.5 W), HIPPO lasers deliver short pulse length (<15 nsec at 40 kHz), high output power (>17 W at 1064 nm) and exceptional beam quality (M2<1.2).

For Free Info Circle No. 734 or Visit www.nasatech.com/Spectra

Telecentric Lenses

Edmund Industrial Optics (Barrington, NJ) is providing Machine Vision Optics (MVO) Telecentric Lenses designed specifically for industrial applications. Available in four magnifications, the lenses provide both high resolution and low distortion. They can be used with CCD sizes as large as 2/3" and provide less than 0.1° telecentricity. All lenses have a front filter thread for the addition of color filters, polarizers, or other mounted components.

For Free Info Circle No. 735 or Visit www.nasatech.com/Edmund



Nano-Sized Connectors

Tyco Electronics (Harrisburg, PA) has augmented its small centerline connector product line with a complete offering of nano-sized connectors. These nano-sized connectors have single-row contacts spaced on 0.025", or, for dual row connectors a 0.0125" centerline spacing is used. Nano connectors are suitable for industrial/commercial applications as well as military, space, and COTS applications.

For Free Info Circle No. 736 or Visit www.nasatech.com/TycoE

Communication Antenna in a Helicopter Rotor

The radiation pattern would not turn with the rotor.

NASA's Jet Propulsion Laboratory, Pasadena, California

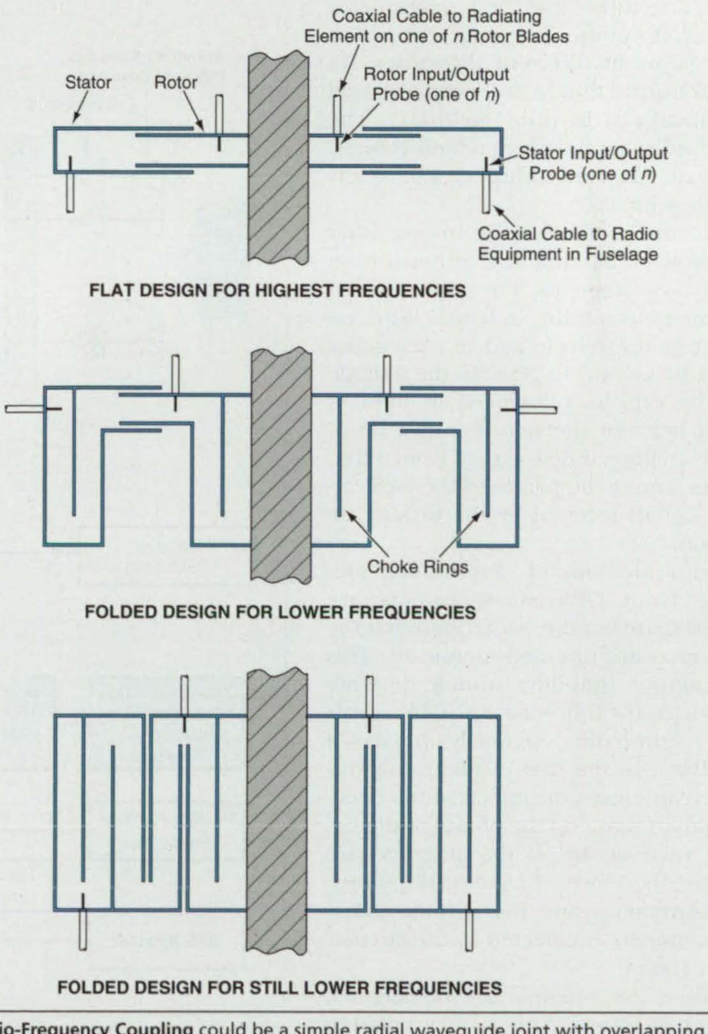
A proposed communication antenna for a helicopter would feature radiating elements in or on the blades of the main rotor, with a novel rotary radio-frequency coupling between the antenna and the radio equipment in the fuselage. The antenna would be suitable for communication along both predominantly horizontal paths (e.g., with distant ground stations) and predominantly vertical paths (e.g., with satellites).

The radiating elements would typically be constructed in one of three forms: (1) The elements could be vertical electric dipoles on the rotor blades; these would transmit and receive in vertical electric polarization. (2) The elements could be horizontal electric dipoles along the blades, in which case they would transmit and receive in horizontal electric polarization. (3) The elements could be horizontal slots on the blades; these would transmit and receive in vertical polarization along horizontal paths, horizontal polarization along vertical paths, and intermediate polarizations along intermediate paths. Horizontal dipoles or slots would ordinarily be preferable to vertical dipoles because they would cause less perturbation of the rotor-blade aerodynamics.

The rotary coupling could be any of several noncontact rotary waveguide joints (see figure). The stator in the rotary coupling would contain a number (n) of input/output probes equal to the number of rotor blades (typically, $n = 5$), positioned at equal angular intervals. The input/output probes in the stator would be connected to a beam-forming network connected via a coaxial cable to the radio equipment in the fuselage. The beam-forming network would be configured so that within the waveguide joint, the radiation would be coupled from the probes (in transmitting) or to the probes (in receiving) in the desired waveguide mode with n-fold azimuthal symmetry. Because the probes would be stationary, this mode would remain stationary.

The rotor part of the rotary coupling would also contain n probes at equal angular intervals. A coaxial cable would couple radiation between each of these probes and the radiating element in or on one of the rotor blades. As the rotor turned, the rotor probes would pass through the stationary n-fold symmetric waveguide mode. This would cause the radio-frequency power coupled between each rotor-blade radiating element and the stationary radio equipment to vary with the instantaneous angle of rotation, so that the radiation pattern traced out by each radiating element alone during one complete rotation would exhibit n-fold symmetry. However, because there would be n blades, this pattern would be spatially modulated with another n-fold symmetry characteristic of the spatial relationships among the n radiating elements. A basic theoretical analysis shows that the net effect of the rotating and stationary n-fold symmetries would be to produce a predominantly azimuthally symmetric (nonrotating) far-field radiation pattern.

The vertical polarization along horizontal paths in the case of horizontal-slot radiating elements would be desirable for communications with ground-based terminals from low altitudes. If either hori-



The **Rotary Radio-Frequency Coupling** could be a simple radial waveguide joint with overlapping parallel disks, or perhaps a more-complex radial waveguide joint that could include choke rings.

zontal electric dipoles or horizontal slots were used, the radiation skyward would be circularly polarized, as would be desirable for communication with satellites.

Because the radiation pattern would not rotate with respect to the airframe, and the rotor blades would not block the radiation, it appears that the proposed antenna would result in much less rotor-blade modulation than is observed when using helicopter antennas of other types. The rotor-blade modulation for this antenna would be limited to that associated with variation in the antenna-element/airframe coupling, with extremes when the center line of the fuselage is aligned with a blade and when it is aligned halfway between two blades. It has been conjectured that this modulation would be small in comparison with the modulation associated with the usual blockage effects.

Yet another advantage would lie in the variation of the phase of the modal radiation pattern with azimuthal angle. Depending on which mode is excited, the relative phase of a received signal could provide a direct measure of the azimuthal angle of arrival of the signal. Thus, while providing omnidirectional coverage in azimuth, this antenna could also be used for azimuthal direction finding.

This work was done by Ronald J. Pogorzelski of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.* *NPO-19803*

GPS Attitude Determination Using Nonaligned Antennas

Phases of circularly polarized signals are corrected for effects of antenna geometry.

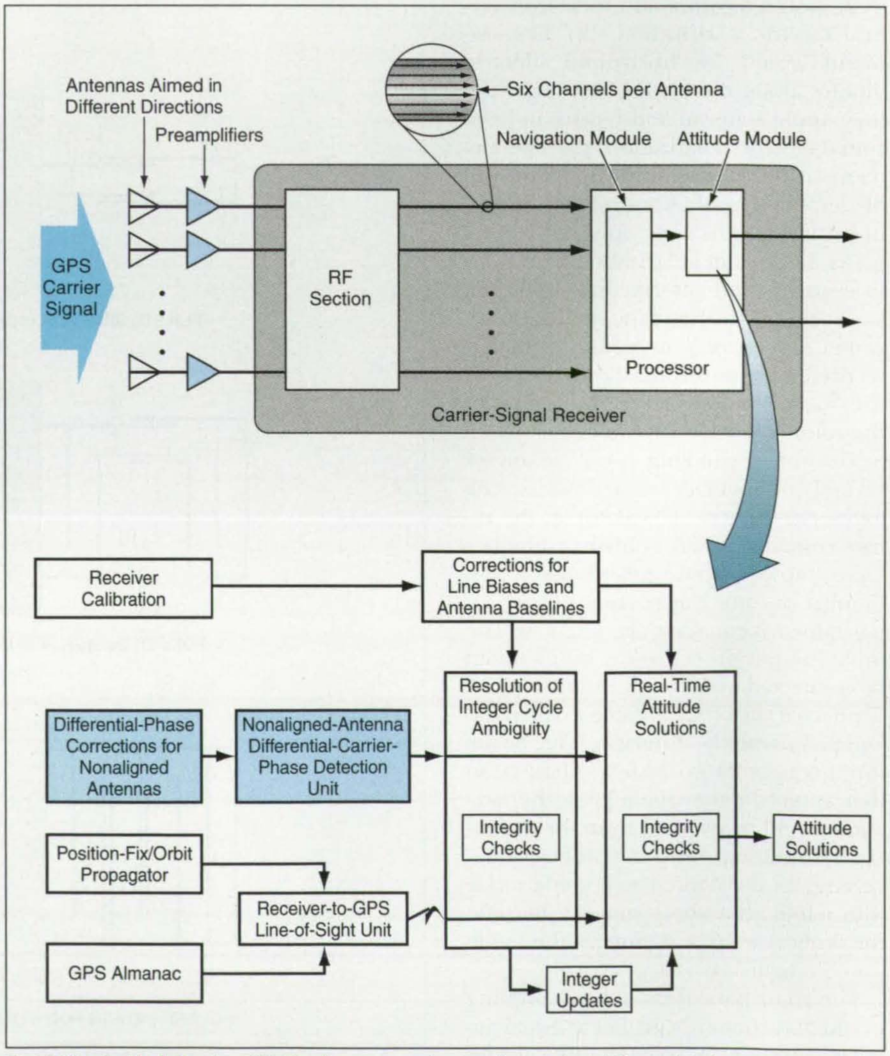
Goddard Space Flight Center, Greenbelt, Maryland

A method of determining the attitude of a vehicle equipped with a Global Positioning System (GPS) receiver with multiple nonaligned antennas has been invented. As used here, "nonaligned antennas" does not signify antennas that lack alignment; rather, it signifies antennas that generally point in different directions (in contradistinction to antennas oriented identically as in prior methods). The method is applicable to a land vehicle, aircraft, spacecraft, ship, or almost any other vehicle.

For the purpose of this or any other method of determining attitude from GPS measurements, the positions and orientations of the antennas with respect to the vehicle and to each other must be known. In general, the attitude of the vehicle, referenced to lines of sight between the vehicle and a set of GPS satellites, is determined from differences among the phases of the GPS carrier signals received by the various antennas.

Prior methods of determining attitude from GPS measurements are based partly on the assumption that the antennas are oriented identically. This assumption simplifies attitude determination in the following way: GPS signals are right-hand circularly polarized (RHCP). In the case of identically oriented antennas, the effects of the circular polarization on the phases of the signals received by all the antennas are equal; therefore, the phase-difference measurements and the attitude determination are unaffected by the circular polarization.

When the antennas are nonaligned, the phase effects of the circular polarization differ among antennas, so that the prior methods cannot be used. In the present method, these effects are taken into account, making it possible to use nonaligned antennas for attitude determination. The major advantage gained through this method is that by using a sufficient number of antennas pointed in different directions, one can maximize the probability that a sufficient number of GPS satellites will be in view



The **Attitude Module of a GPS Receiver** runs software that makes differential-phase corrections for RHCP GPS signals received by nonaligned antennas.

Faster, easier device characterization

Flexible DC/RF switch and measure systems in one easy-to-use instrument

Cost-effective PCI plug-in boards

Sub-femtoamp Remote SourceMeter®

at any given time, making it possible to determine the current attitude of the vehicle, regardless of its position, attitude, or state of motion (the vehicle could even be tumbling).

The figure schematically depicts selected aspects of a typical GPS receiver system that implements the present method. Preferably, there are eight antennas and the radio-frequency (RF) section of the receiver can accommodate as many as six GPS channels per antenna. The signals in the various channels are digitized, then sent to a processor that includes a navigation module and an attitude module. The navigation computations and most of the attitude computations are performed according to conventional GPS methods. The distinct aspect of the present method lies in the software of the attitude module. This software provides phase-difference corrections based on the calculable effects of (1) the known relative positions and orientations of the antennas and (2) the phases of the RHCP GPS signals that they receive.

The primary obstacle to incorporating the RHCP phase-difference corrections into the attitude computations is the fact that the attitude of the vehicle is embedded in expressions of the reference frames of the various antennas. A circular-reasoning condition arises in that to calculate the attitude, it is necessary to know the RHCP corrections, but to calculate the RHCP corrections, the attitude must be known. If the attitude of the vehicle is already approximately known, perhaps from a prior estimate, the RHCP phase corrections can be estimated and then iterated, along with a new attitude solution, to convergence toward a final attitude solution. If no prior estimate of attitude is available, then an initial estimate can be constructed, for example, by use of the line of sight from each antenna to the source of the strongest GPS signal received on that antenna.

This work was done by Edgar Glenn Lightsey of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

This invention has been patented by NASA (U.S. Patent No. 6,005,514). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13907.

A Semiautomated Coordinate-Measuring System

John F. Kennedy Space Center, Florida

The Advanced Payload Transfer Measurement System (APTMS) comprises electromechanical sensors and sensor-output-processing circuits. Designed specifically for measuring offsets between spacecraft payload trunnions and trunnion supports during ground-based payload-transfer operations, the APTMS could be adapted to general measurement of offsets for guiding movement of large objects during assembly of heavy machinery or structures. An electromechanical sensor of the type used in the APTMS was described in "Spherical-Coordinates Encoder Module" (KSC-11973), *NASA Tech Briefs*, Vol. 24, No. 2 (February 2000), page 52. Initially, the sensor outputs were fed via cables to a portable computer for analysis and display. More recently, the sensors and computer were equipped with wireless transceivers capable of communicating in either a time-division- or a spread-spectrum multiplex mode to eliminate the need for cables, thereby contributing to maneuverability and safety in the workspace. An important element of the design and operation of the system is taking calibration measurements and processing of these measurements by curve-fitting software to piecewise-linear offsets to correct for systematic errors in raw sensor outputs in order to obtain accuracy within 0.05 in. (≈1.3 mm) at distances ≤ 40 in. (≈1 m).

This work was done by Felix A. Soto Toro of **Kennedy Space Center** *and Wasfy Mikhael of the University of Central Florida. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Commercialization Office, Kennedy Space Center, (321) 867-8130. Refer to KSC-12204/3/195.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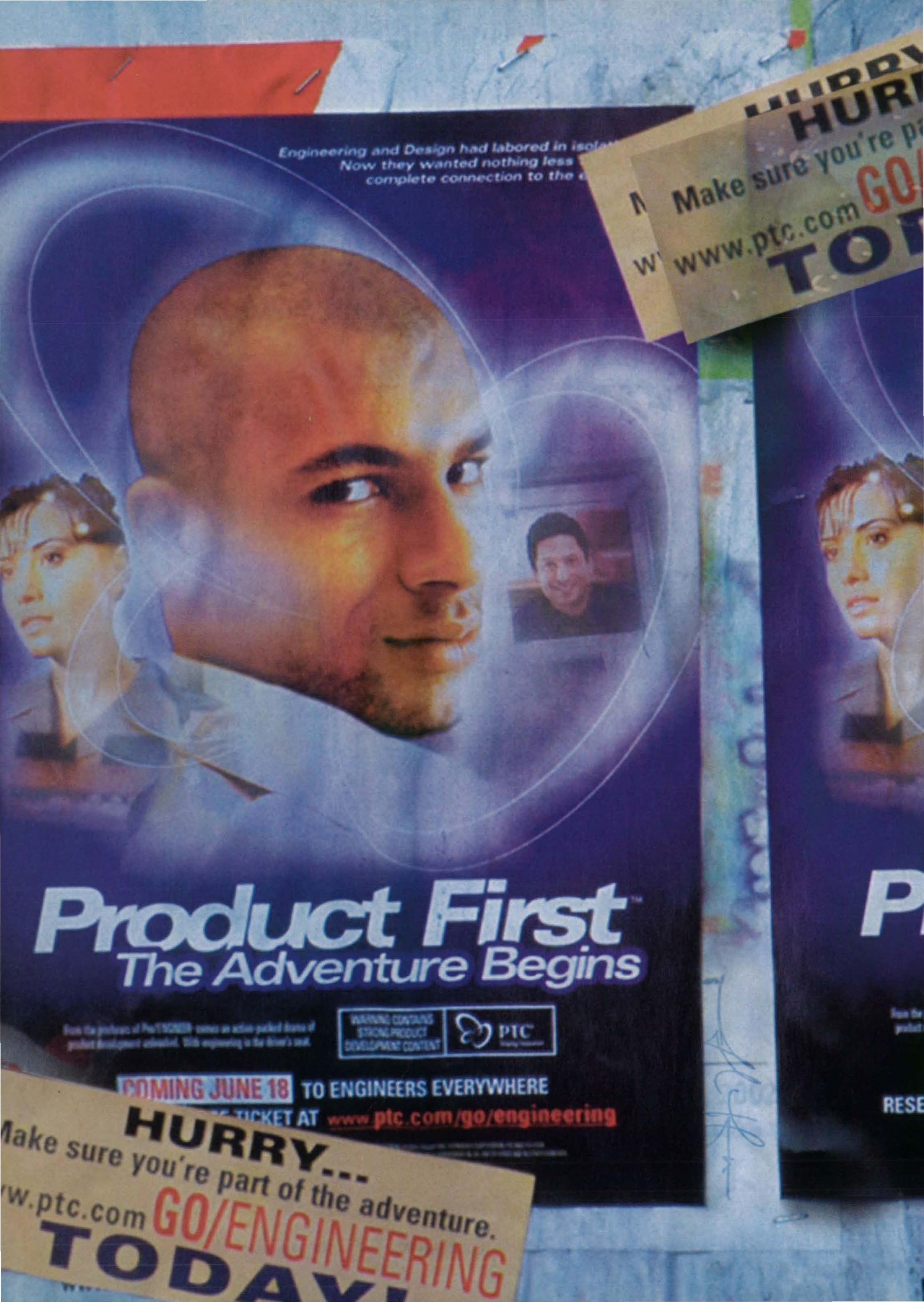
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Software Provides Thermal Optimization of a Computer CPU

A FEA-based, multiphysics analysis tool analyzes the water cooling system of a computer CPU to improve product durability.

ALGOR, Inc., Pittsburgh, Pennsylvania

Heat is the primary enemy of any electronic component. In order for an electronic device to have a long, problem-free life, cooling must be an important design consideration. The problem of cooling CPUs, in particular, has grown as processors have become more powerful. Water cooling systems are one option for keeping blazing-fast CPUs cool. As an example, engineers used finite element analysis (FEA)-based, multiphysics analysis software to consider whether a proposed water cooling system design would regulate CPU temperature in order to meet the manufacturer's recommendations.

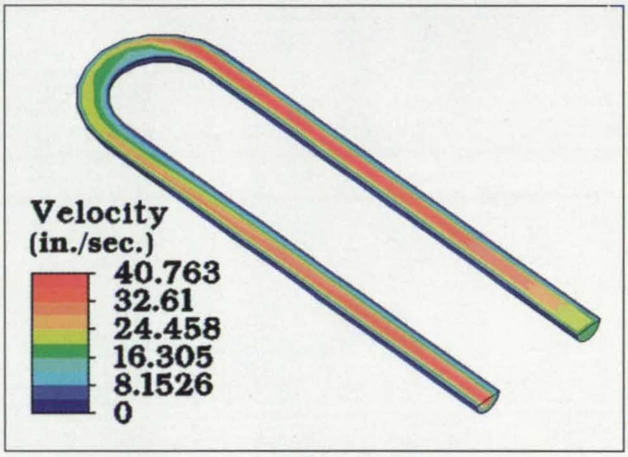

Figure 1: This ALGOR **Fluid Flow Analysis** shows the fluid velocity profile through the water tube inside a computer CPU cooling system.

Simple heat dissipation methods, such as adding heat fins and relying on natural convection, have often been sufficient for electronics. However, as devices become more powerful, it becomes increasingly important to produce the flow of a fluid to create forced convection for greater cooling capacity. The fluid may be air-moved by a fan or water within a water cooling system. The key is to produce a sufficient amount of forced convection to keep a device within its recommended operating temperature range during sustained use.

FEA-based, multiphysics analysis software provides engineers designing electronic components with a tool to determine the required flow velocities. As an electronics OEM and provider of wireless communications equipment, Wytec of Santa Clara, CA, needed to know what fluid flow velocity was necessary to cool the electronics. ALGOR's forced convection capability determined what level of fluid flow would produce the desired temperatures and prevent the electronics from overheating and failing.

The water cooling system was modeled in ALGOR. A fluid flow analysis was then performed based on an inlet velocity of 20 in./sec. to obtain a velocity profile throughout the water tube. The inlet velocity of 20 in./sec. was used because it is a common flow rate for an off-the-shelf small pump. This velocity profile was then used as input to the heat transfer analysis to simulate forced convection. In addition to the forced convection input, an internal heat generation load considered 29.5 watts of energy from the CPU, a specified temperature of 70°F was applied at the inlet, and another convection load accounted for heat loss through natural convection to ambient air. The steady-state heat transfer analysis produced a temperature profile throughout both the water and cooling block with the maximum temperature reaching 82°F.

The multiphysics analysis was then repeated with a water inlet velocity of 0 in./sec. In this case, the maximum temperature reached 220°F. The analysis verified that the system would successfully cool the CPU with a water flow rate of 20 in./sec. and thereby support reliable performance over the life of the computer.

For more information on using ALGOR's multiphysics analysis products, including the forced convection capability, contact **ALGOR, Inc.**, *150 Beta Drive, Pittsburgh, PA 15238; Tel: 1-800-48-ALGOR; or visit the Web site at: www.ALGOR.com* .

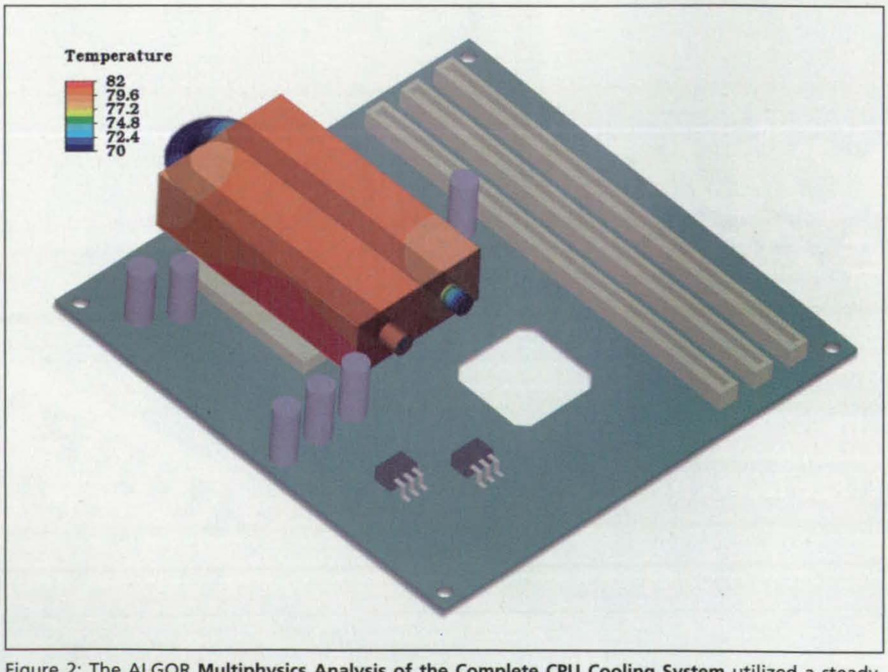

Figure 2: The ALGOR **Multiphysics Analysis of the Complete CPU Cooling System** utilized a steady-state heat transfer analysis that considered the fluid flow velocity results from the water tube when determining the final temperature distribution in both the water and cooling block.

Software for Automated Planning of Spacecraft Missions

NASA's Jet Propulsion Laboratory, Pasadena, California

An artificial-intelligence computer program generates and evaluates plans for spacecraft missions subject to constraints associated with spacecraft designs. The input to the program includes spacecraft design parameters (e.g., slew rates and battery capacities) and mission parameters (e.g., requested scientific observations, frequency of communication passes, and trajectory). The program generates a mission-activity plan for attaining mission goals without violating constraints (e.g., for making all desired observations within the available time). The program makes it possible to perform rapid evaluations of multiple candidate designs against a given mission scenario by generating plans for each design and automatically evaluating them against objective criteria. Alternatively, the program can also be used to perform "what-if" evaluations. This program can be used early in the spacecraft-design and spacecraft-mission-planning process, thereby helping to ensure that a spacecraft design and mission plan are consistent with each other; more specifically, the program can show how a given design can be expected to perform in a given mission scenario, and on the basis of the program output, one can modify the design and/or the mission to improve performance.

This program was written by Steve Chien, Barbara Engelhardt, Darren Mutz, Russell Knight, Gregg Rabideau, Robert Sherwood, Ben Smith, Colette Wilklow, and Jason Willis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21000.

Generalized-Time-Line Program for Planning and Scheduling

NASA's Jet Propulsion Laboratory, Pasadena, California

Generalized Timelines API is a computer program that provides (1) a means of representing arbitrary real-world state and resource information for use in planning, scheduling, and plan- and schedule-executing software and (2) an application-programming interface (API) that accelerates the development and validation of the software. In prior time-line programs, constraints had not been regarded as parts of time lines, and it was difficult to represent constraints. For the present program, a time line is defined as a representation of the actual and/or predicted value(s) of a variable and a set of constraints on the variable, both at successive intervals of time. The program (1) enables assignment of values to variables and modeling of the constraints on the variables, all as functions of time; (2) makes it possible to determine whether the values are consistent with the constraints; and (3) provides "hooks" to the search space represented by the variables for the purpose of optimizing plans. This program enables computer-programming specialists to engage in research on, and development of, scheduling application programs separately from the efforts of other specialists to implement time lines specific to their domains of expertise. In comparison with prior software of the same type, this program is representationally sufficient for more domains.

This program was written by Steve Chien, Russell Knight, Kim Gostelow, Tom Starbird, Gregg Rabideau, and Robert Sherwood of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

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Improvements in the Use of Water Washes in Testing for NVR

Effectiveness of washing and sensitivity of detection are increased.

John F. Kennedy Space Center, Florida

Some improvements have been made to enhance the role of water as a test solvent for determining the amount of hydrocarbon nonvolatile residue (NVR) present on an item of hardware that is required to be totally or nearly devoid of such residue. Water is now used as an NVR-testing solvent because (1) even high-molecular-weight hydrocarbon greases are at least slightly soluble in water, (2) water is safer and less expensive than are chlorofluorocarbon solvents [in particular, 1,1,2-trichloro-1,2,2-trifluoroethane (also known as CFC-113), which was used previously in testing for hydrocarbon NVR], and (3) CFC solvents are expensive and are now recognized as environmentally harmful.

The present improvements address two major aspects of the NVR-testing problem: (1) increasing the efficiency of removal of NVR from hardware by use of water and (2) increasing the sensitivity of measuring the concentration of NVR dissolved in the water. Prior to these improvements, it was known that when small parts are subjected to ultrasound in a water bath and NVR is present, the amount of NVR dispersed into the water is sufficient to enable measurement of the concentration of the dissolved NVR by the total-organic-carbon (TOC) method.

The present improvements extend the applicability of water-wash NVR testing to parts too large to fit in an ultrasonic bath. The efficiency of removal of NVR from a large part can be increased somewhat by use of steam or high-pressure spray of water, with or without a gas mixed in. However, the technique found to be most efficient (and least dependent on the size of the part) is spraying water on the surface of the part from an ultrasonic nozzle.

The increase in the sensitivity of measurement is achieved by concentrating the NVR from the wash water before attempting the measurement. For this purpose, all of the wash water is made to flow through a bed of silica gel. During this flow, a significant portion of the dissolved NVR becomes adsorbed onto the silica gel particles. Then part or all of the silica gel is analyzed by the TOC method. Tests have shown that by use of both ultrasonic spraying of water and measurement of the TOC of silica gel through which the wash water has passed, it is possible to measure areal concentrations of NVR as

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low as 0.05 mg/ft^2 (≈0.5 mg/m^2) on the surfaces of parts under test.

This work was done by Christian Clausen III of the University of Central Florida for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*
KSC-12129

Using Polyimide Tape To Mask Against Reactive-Ion Etching

This technique is cheap, simple, and effective.

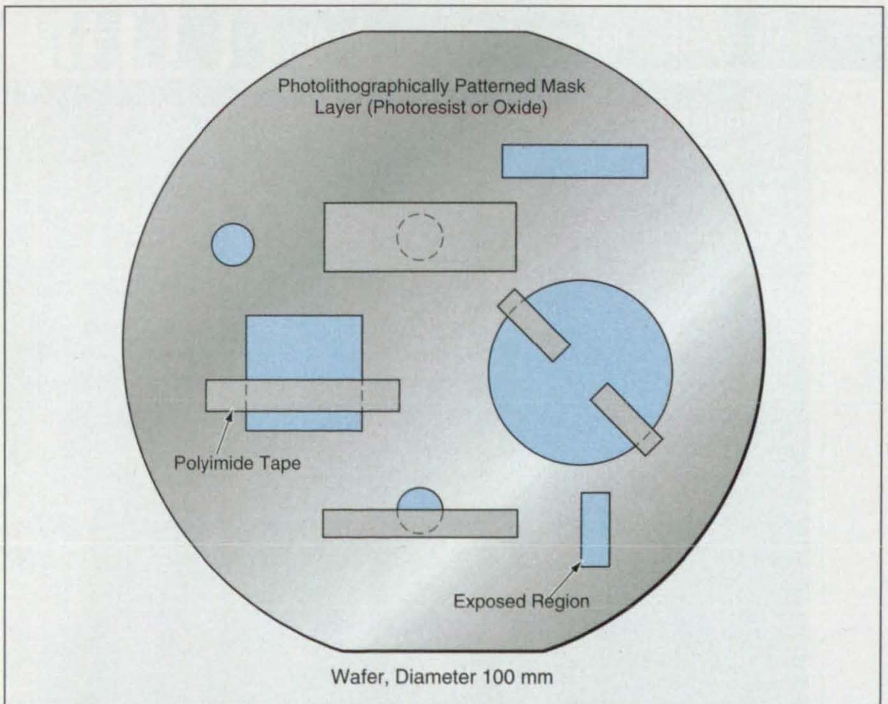
NASA's Jet Propulsion Laboratory, Pasadena, California

Polyimide tape (Kapton™ or equivalent) has been found to be effective as a material for masking selected areas of a semiconductor wafer that is about to be processed in a reactive-ion etching (RIE) apparatus. The conventional etch-resistant masking materials for protecting selected areas against etching are photoresists and oxides. These materials are patterned into masks by standard photolithographic techniques. The use of polyimide tape is an inexpensive option that provides additional flexibility for increasing the protection of some areas and for implementing last-minute design changes without having to incur the high cost of making optical masks for photolithography.

The tape is cut to fit the areas that are to be protected against etching, then secured to the wafer by use of its own adhesive backing (see figure). The tape is smoothed down to remove pockets of air that would otherwise become trapped between the wafer and the adhesive. The tape is thin enough (≈50 µm) that it can easily be made to conform to previously patterned changes in surface height. When the RIE process is finished, the tape is simply pulled off.

In experiments, polyimide tape proved effective in preventing RIE of masked areas. Specimens of tape that were exposed to RIE and vacuum for as long as 3 hours exhibited no measurable change in thickness, no loss of adhesion, no changes in color, and no melting or other surface changes.

This work was done by Stephen Vargo of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*
NPO-20598



Pieces of Polyimide Tape are applied to areas designated to be protected (or additionally protected) against RIE. During the RIE process, the ions are incident along the perpendicular to the plane of this drawing.

Hexfoil Rotary Flexures

These devices would afford high accuracy of centration.

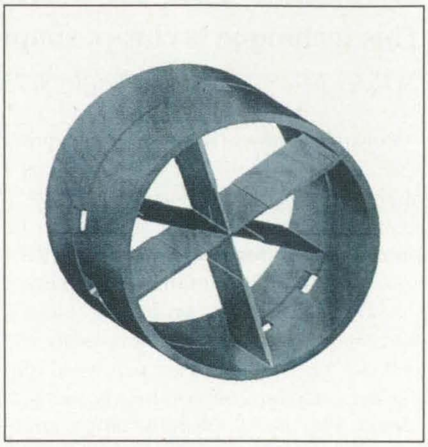
NASA's Jet Propulsion Laboratory, Pasadena, California

Hexfoil rotary flexures have been proposed as pivots suitable for use in precise optical instruments. In the application that inspired the hexfoil concept, there is a requirement for a limited-rotation mirror gimbal that would maintain, with unprecedented accuracy, coincidence among the axes of rotation and a fiducial mark on the mirror, over the entire range of rotation. Theoretically, a hexfoil rotary flexure could satisfy this requirement.

A hexfoil rotary flexure would offer the following advantages over a nominally equivalent commercial rotary flexure:

- A hexfoil rotary flexure would maintain a static center of rotation; in other words, it would be subject to no more than negligible drift of the center of rotation.
- The ratio between lateral stiffness and rotational stiffness (this ratio is regarded as a figure of merit for a flexural pivot) would be much greater. Thus, a hexfoil would approximate an ideal pivot more closely.
- An optimized hexfoil rotary flexure could withstand a lateral load greater than that for any similarly sized commercial flexural pivot.
- A hexfoil rotary pivot would be made from a single piece of material. The monolithic nature of this device would ensure the highest reliability.

The hexfoil rotary flexure is related to the device described in "Trefoil Rotary Flexure" (NPO-20228) *NASA Tech Briefs*, Vol. 22, No. 8 (August 1998), page 68. In comparison with a trefoil pivot, a hexfoil pivot would have twice the angular range,



A **Hexfoil Rotary Flexure** would feature a favorable load-bearing configuration and a high degree of symmetry, such that the application of torque about the cylindrical axis would result in exceptionally pure rotation, even in the presence of axial and lateral loads.

while sacrificing some lateral stiffness and load capability. A hexfoil pivot could be designed as a drop-in replacement for a standard Lucas (or equivalent) pivot, inasmuch as it has the same type of interface.

A hexfoil pivot (see figure) would include two coaxial hollow circular cylinders that would constitute a rotor and stator, respectively. From each cylinder, three flexural elements in the form of thin plates spaced at equal circumferential intervals would extend radially inward, terminating at approximately the axis of rotation. More precisely, the plates attached to each cylinder would be parallelograms with bases equal to the length of the cylinder, radial heights approximately equal to the inner radius of the cylinder, and an axial slant distance of approximately half the length of the cylinder. Thus, in effect, the three flexural elements from each cylinder would terminate in a line segment of length equal to that of the cylinder, coincident with axis of rotation, displaced axially from the cylinder by half the length of the cylinder.

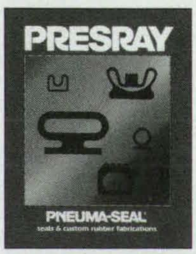
To complete the characterization, it should be mentioned that the on-axis flexure termination for each cylinder would be displaced axially toward the other cylinder, such that the flexure terminations for both cylinders would coincide. Furthermore, the flexural elements for the two cylinders would be "clocked" relative to each other such that each flexure from one cylinder would be coplanar (when not deflected) with one from the other cylinder. Hence, in essence, there would be three contiguous flexures connecting the two cylinders.

The advantages of this configuration are the following:

- The termination of the flexural elements would be brought as close as possible to the axis of rotation, thereby maximizing the rotational flexibility while maintaining lateral stiffness.
- Load paths through the device would be aligned such that all translational loads would be carried as tension or compression in the flexural elements (the stiffest and highest-load-bearing arrangement possible), while a torque applied about the axis of rotation would be reacted by simple bending (configuration of greatest compliance and least stress).

This work was done by Donald Moore and Robert Calvet of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

NPO-21154



Flight Research on Supersonic Laminar Flow

Flow over a suitably designed airfoil can remain largely laminar, even at supersonic speed.

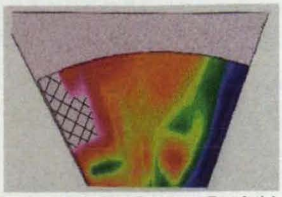
Dryden Flight Research Center, Edwards, California

Some airfoil designs have been shown by theory and small-scale tests to be capable of passively maintaining laminar flow at supersonic speeds. More recently, flight tests have proven that these designs can maintain large runs of laminar flow at higher Reynolds numbers in harsh flight environments. The flight tests were conducted for the purposes of observing laminar flow at speeds up to mach 2.0 and determining the conditions under which laminar flow breaks down.

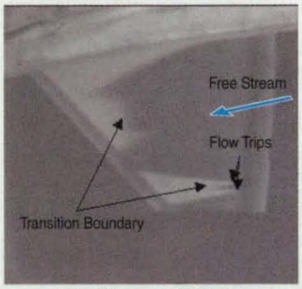
Flight tests were performed on an F-15B airplane equipped with a laminar-flow test article — essentially, a small

half wing mounted vertically (see figure). The airplane was also equipped with an infrared camera for observing the test article flow. In effect, the camera measures the local surface temperature of the test article, which temperature varies with the state of the boundary-layer flow: The portion of the surface covered by a turbulent boundary layer is warmer than that covered by a laminar boundary layer — a consequence of its higher wall recovery temperature as well as greater convection of the turbulent layer with the free-stream flow. Hence, in the infrared image, the surface in the turbulent-flow region appears brighter than that in the laminar-flow region.

The test article was fabricated from aluminum with an insulating layer covering all but the first 3 to 4 in. (about 7.5 to 10 cm) in from the leading and trailing edges. A splitter plate was installed at the root of the test article to minimize the effect of disturbances from the bottom of the airplane on the flow about the test article and to better simulate a full-span wing.


Predicted Transition Pattern on Test Article (Cross-Hatched Area Denotes Transition)


Article Mounted on F-15B Aircraft



Infrared Image of Test Article

The **Boundary of the Transition** from laminar to turbulent flow is visible in an infrared image of the test article taken during supersonic flight.

Laminar flow was observed up to full chord on the outer third of the span of the test article and up to approximately 80 percent of chord over the inner two-thirds of the span. The laminar flow was found to be capable of penetrating weak shock waves, but was typically terminated by strong shock waves. The strongest shock wave incident on the test surface appeared to emanate from the camera pod, which was located on an armament rail of the airplane.

For future flights, the test article will be instrumented with surface-pressure gauges and thermocouples to obtain more detailed data. Also, the video data-recording system will be updated to enable it to record the full 12-bit digital images from the camera. A contemplated subsequent program would use a larger test article that would permit assessment of effects of greater Reynolds numbers.

This work was done by Daniel W. Banks of **Dryden Flight Research Center** *and Richard R. Tracy and James D. Chase of Reno Aeronautical Corporation, a subsidiary of Directed Technologies, Inc. Further information can be obtained from Daniel Banks [telephone no. (661) 276-2921 or e-mail* dan.banks@dfrc.nasa.gov*].*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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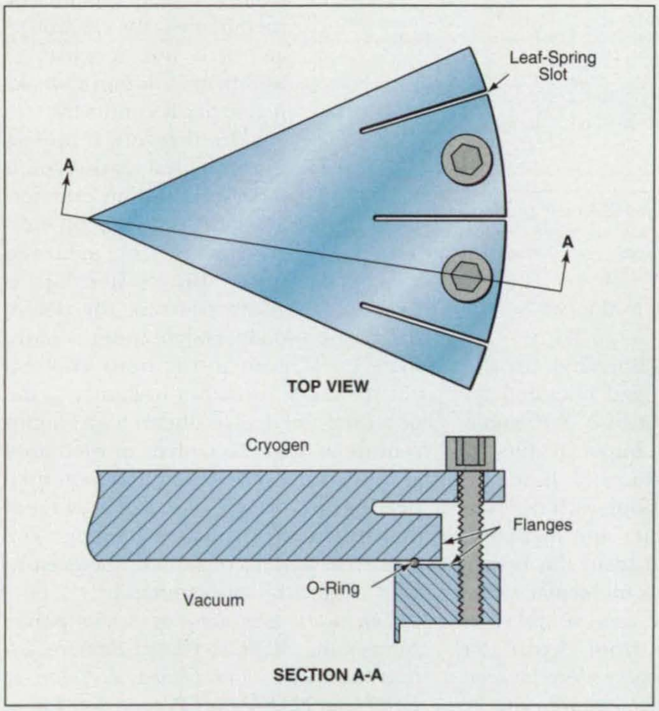
Refer to DRC-00-22, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Flange Design for Cryogenic Vacuum O-Ring Seals

Spring-loaded joints could be made less bulky.

NASA's Jet Propulsion Laboratory, Pasadena, California

A compact spring-loading design has been proposed to increase the reliability of seals in the joints of vacuum cryogenic systems. Heretofore, such joints have been, variously, compact or reliable, but not both, for the following reasons: In all such joints, sealing is effected by compression of soft metal (typically, indium or alloys of indium) O rings between flanges. Over time, the soft O-ring metal flows, with consequent reduction of preload, sometimes leading to loss of seal. To ensure reliable seals, it is necessary to spring-load the flanges to maintain compression of the O rings. However, spring-loaded joints of traditional design are not compact.



The **Outer Portion of One of the Flanges** would be cut to form leaf springs, which would be used for spring loading of the O ring.

The proposed compact spring-loading design is related to a prior noncompact design in which (1) one of the flanges of a joint is cut so that it acts somewhat like a leaf spring and (2) the bolt-circle diameter of the flange is made considerably greater than the major diameter of the O ring so that the flange can bend elastically and its deflection is spread out over the annulus between the O ring and the bolt circle. In the proposed design, leaf springs with a thickness less than that of the flange would be formed in the bolt-circle region by cutting a combination of meridional (radial-axial) and annular slots in the flange, as shown in the figure. This design would afford the elasticity needed for spring loading, without need to make the bolt circle much larger than the O ring.

This work was done by Bob Bamford, Talso Chui, and Warren Holmes of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
NPO-21006

Making Hydrogen by Electrolysis of Methanol

The cost is about half that of making hydrogen by electrolysis of water.

NASA's Jet Propulsion Laboratory, Pasadena, California

Scientists at NASA's Jet Propulsion Laboratory are developing apparatuses for electrolysis of methanol to produce pure hydrogen for use at industrial sites, in scientific laboratories, and in fuel cells. The state-of-the-art onsite hydrogen generators now in use are based on electrolysis of water to produce hydrogen, with oxygen as a byproduct that has no commercial value in this context. The developmental methanol electrolyzers consume less than half the electrical energy of water electrolyzers in producing a given amount of hydrogen. Even when the cost of methanol is included, the cost of producing hydrogen by electrolysis of methanol is still only about half that of producing hydrogen by electrolysis of water.

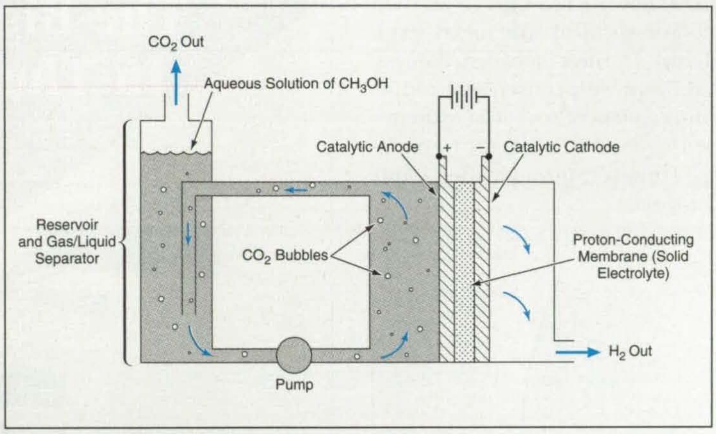


Figure 1. **Methanol Is Electrolyzed** to hydrogen (the main product) and carbon dioxide (the byproduct). The carbon dioxide is vented, while the hydrogen is purified with a molecular sieve to remove traces of water and methanol before use.

Figure 1 schematically illustrates a methanol-electrolysis apparatus. The heart of the apparatus is an electrolysis cell that contains a unitary membrane-electrode structure. Typically, this structure comprises a solid electrolyte in the form of a proton-conducting polymeric membrane, with a catalytic anode (e.g., containing a Pt/Ru catalyst) deposited on one side and a catalytic cathode (e.g., containing Pt or Pd as the catalyst) deposited on the other side — as described, for example, in "Improved Fabrication of Electrodes for Methanol Fuel Cells" (NPO-19941), *NASA Tech Briefs*, Vol. 23, No. 4 (April 1999), page 38.

An aqueous solution of methanol is circulated past the anode, where methanol and water undergo the reaction

$$CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$$

The hydrogen ions pass through the membrane to the cathode, where they are reduced to hydrogen molecules in the reaction

$$6H^+ + 6e^- \rightarrow 3H_2$$

Thus, the net reaction in the cell is

$$CH_3OH \rightarrow CO_2 + 3H_2$$

with carbon dioxide liberated on the anode side and hydrogen liberated on the cathode side. Because the membrane is not totally impermeable by water and methanol, traces of these substances pass through along with the protons. However, the water and methanol can easily be removed from the hydrogen stream by use of a molecular sieve, as is routinely done to remove traces of water and oxygen from hydrogen streams produced in water electrolyzers.

If the solid-electrolyte membrane in the cell is made of Nafion™ (or equivalent) perfluorosulfonic acid-based proton-conducting polymer, then the cell can be operated in the temperature range from 5 to 120 °C. The concentration of methanol in the aqueous solution can range from 0.1 to 8 molar. The membrane is the electrolyte, and it is not necessary to acidify the solution to make it electrically conductive.

The theoretical operating potential of the cell is 0.02 V, though in practice, a useful amount of electrolysis is not achieved until the potential is raised to 0.3 V. In contrast, the potential needed to electrolyze water is more than 1.4 V, even in the most efficient electrolyzers. As shown in Figure 2, the potential needed to obtain a given current density in electrolysis of methanol is more than 1 V below the potential needed to obtain the same current density in electrolysis of water. The electrical power consumed in electrolysis is reduced proportionately.

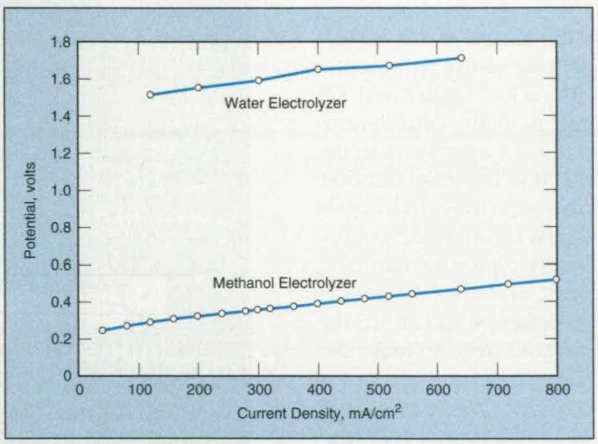


Figure 2. **Less Voltage** is needed to electrolyze methanol than to electrolyze water at the same current density, as indicated by these plots of data from an experiment with a prototype methanol electrolyzer and a commercial water electrolyzer.

This work was done by Sekharipuram Narayanan, William Chun, Barbara Jeffries-Nakamura, and Thomas I. Valdez of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-19948, volume and number of this NASA Tech Briefs *issue, and the page number.*

Aircraft-Mounted Cloud-Water-Content Probe

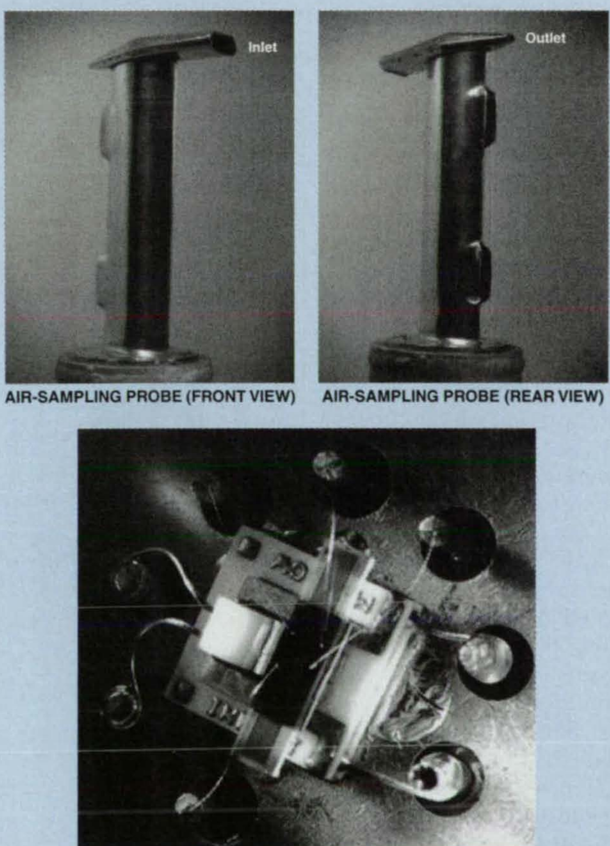
This relatively simple instrument contains no heater or pump.

NASA's Jet Propulsion Laboratory, Pasadena, California

An aircraft-mounted instrument for high-resolution, *in situ* measurement of the abundances of liquid water and ice in clouds is undergoing development. This instrument is intended to overcome the disadvantages of instruments developed previously for the same purpose. The disadvantages include various combinations of complexity, dependence on heaters and/or pumps, insensitivity to ice crystals, or dependence on droplet/crystal size. The present instrument is relatively simple, does not include a heater or a pump, and is expected (when fully developed) to be sensitive to both water droplets and ice crystals of any size.

In principle, the fully developed version of the instrument would contain (1) a first air-sampling probe based a total-temperature probe, (2) a second air-sampling probe that would reject water droplets and ice crystals, and (3) two fast-reading electronic hygrometers — one for each probe. A simplified prototype of the instrument has been built from a modified commercial total-temperature probe and a surface-acoustic-wave hygrometer (see figure).

By virtue of its total-temperature feature, the first air-sampling probe would bring the incident airflow to rest (except for a slow internal sampling flow), thus raising the temperature of the sam-



The **Air-Sampling Probe** feeds an aerodynamically heated sample stream to the surface-acoustic-wave hygrometer.

pled air. This aerodynamic heating would cause entrained water droplets and ice crystals to evaporate. The sample stream containing the water vapor generated by aerodynamic heating would be routed to the associated first hygrometer, which would thus be made to measure the total water content (vapor, liquid, and ice) of the ambient air.

The sample stream from the second probe would be routed to the associated second hygrometer, but, unlike the sample stream from the first probe, this stream would not contain the vapor from the water droplets and ice crystals; that is, its vapor content would consist solely of the ambient-air vapor. Then one could subtract the vapor reading of the second hygrometer from the vapor+liquid+ice reading of the first hygrometer to determine the liquid+ice content.

Of course, the cloud-water-content determinations made by use of the instrument depend largely on the assumption that all of the droplets evaporate and all of the ice crystals sublimate in the first probe as a result of aerodynamic heating (and, possibly, of impact upon the probe wall). It is planned to assess the validity of this assumption in tests in a wet wind tunnel.

This work was done by Flavio Noca and Michael Hoenk of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at*** *www.nasatech.com/tsp under the Physical Sciences category.*
NPO-20767

Miniature NMR Spectrometers Without Magnets

These spectrometers would be used to characterize ferromagnetic minerals.

NASA's Jet Propulsion Laboratory, Pasadena, California

Miniature, lightweight nuclear-magnetic-resonance (NMR) spectrometers suitable for characterizing ferromagnetic minerals in the field are undergoing development. In previously developed miniature NMR spectrometers, more than half the weight is contributed by permanent magnets. The present developmental miniature NMR spectrometers can be made much lighter because they do not contain permanent magnets: Unlike other NMR spectrometers, they are designed to operate without applied magnetic fields; instead, they exploit the natural magnetic fields of the mineral phases to be studied.

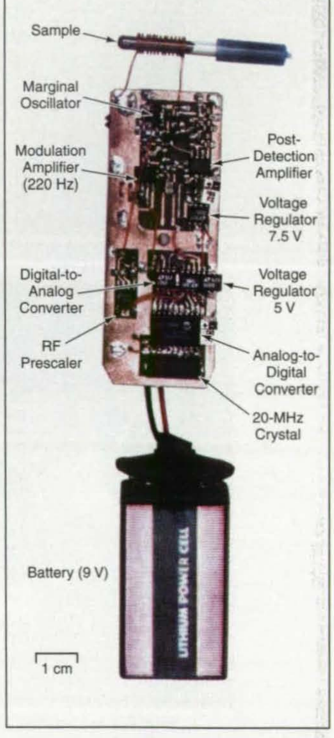


Figure 1. This **Miniature NMR Spectrometer** has a mass of only 65 g (this includes the battery) and consumes a power of only 0.2 W.

Figure 1 shows a prototype instrument of this type designed to exploit the natural magnetic fields in minerals that contain iron. These fields give rise to nuclear magnetic resonance

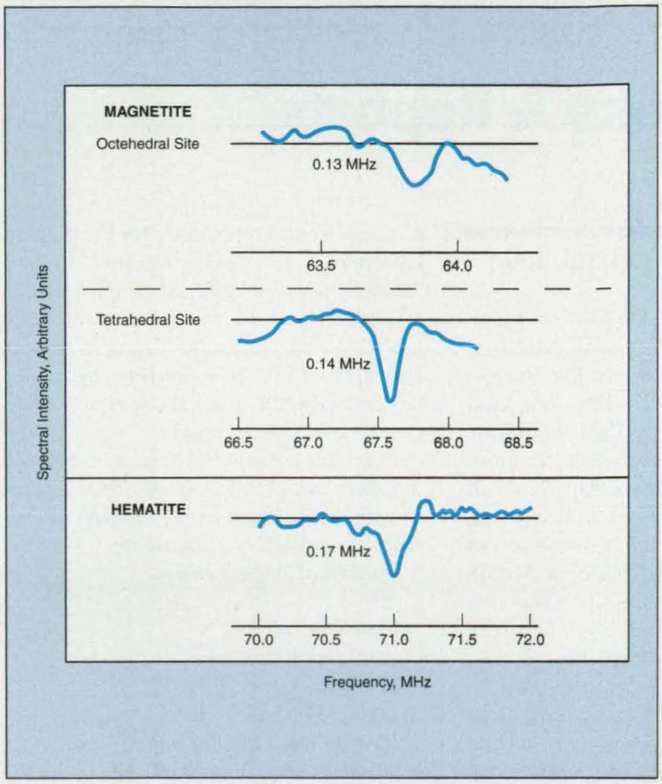


Figure 2. These **NMR Spectra** of specimens of magnetite and hematite were obtained by use of the instrument shown in Figure 1.

of the isotope ^{57}Fe at frequencies in the approximate range of 60 to 74 MHz. Resonances occur at specific frequencies associated with mineral phases of interest. For example, magnetite (Fe_3O_4) exhibits a resonance at 63.8 MHz for $^{57}Fe^{3+}$ ions in octahedral sites (coordination with oxygen atoms) and another resonance at 67.6 for $^{57}Fe^{3+}$ at tetrahedral sites.

This instrument includes a marginal oscillator, the frequency of which is determined mainly by tuning capacitors, two varactors, and the NMR sample coil, in which a mineral specimen is placed. During operation, the frequency is swept slowly by use of one varactor, and is modulated at a rate of 110 Hz by use of the other varactor. The instrument also includes a digital-to-analog and an analog-to-digital converter and a microprocessor that communicates with an external laptop computer, generates frequency-sweep and modulation signals, samples the output from the oscillator, and performs synchronous detection.

The instrument is connected with the computer via a telephone (RS232) cable. Such parameters as the scan range, scan rate, number of averages, and time constant can be set through the computer keyboard. Spectral data can be displayed on the computer screen. The software in the computer includes routines for processing data to estimate concentrations of mineral phases of interest.

The performance of the instrument was demonstrated in NMR measurement experiments on two mineral specimens: one that contained magnetite in chlorite schist mixed with magnetically inert particles and one made of hematite (α–Fe_2O_3). The spectra obtained from these specimens (see Figure 2) show the expected magnetite resonances and a hematite resonance at about 70.8 MHz.

This work was done by Soon Sam Kim, Narayan Mysoor, and Christopher Ulmer of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.* *NPO-20106*

Books & Reports

MEMS Design Optimization With FEA

This report examines design considerations in one of the most promising new areas of engineering – Micro Electro Mechanical Systems (MEMS). Designing and optimizing MEMS devices involves unique challenges, including analyzing the interdependent physical phenomena to which MEMS devices are sensitive and working with small-scale geometry. A discussion of the necessary steps to model a MEMS micro-heater for an automotive gas sensor array that can withstand high temperatures is presented in this article.

This work was a collaborative effort between Walied Moussa, Ph.D., of the University of Alberta in Edmonton, Alberta, Canada; and **ALGOR, Inc.**, *Pittsburgh, PA. To obtain a copy of the report, "MEMS Design Optimization with FEA," visit http://optimizemems.algor.com.*

Further Developments Regarding Noise-Reducing Slots in QWIPs

A report presents additional information on the devices described in "Noise-Reducing Slots in Quantum-Well Infrared Photodetectors" (NPO-20518), *NASA Tech Briefs*, Vol. 25, No. 6 (June 2001), page 6a. To recapitulate: it was proposed that incorporation of suitably dimensioned crossed slots into quantum-well infrared photodetectors (QWIPs) equipped with two-dimensional surface grating light couplers would reduce dark currents and increase detectivities. Going slightly beyond that proposal, the report proposes optionally filling the slots with low-index-of-refraction dielectric material. Going beyond the previous discussion, the report notes that finite-difference solution of the Helmholtz equations for electromagnetic coupling into a slotted QWIP leads to the conclusions that (1) the slotted QWIP acts as an array of leaky waveguides or weakly coupled cavity resonators; (2) coupling can be maximized by choosing the width, spacing, and index of refraction of the slots to obtain resonance at the desired wavelength of operation; and (3) the coupling in such a case is stronger and more broad-band, relative to the coupling into a nonslotted surface-grating QWIP.

This work was done by Daniel Wilson, Sarath Gunapala, Sumith Bandara, and John K. Liu of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Slotted Quantum Well Infrared Photodetector for Reduced Dark Current and Enhanced Optical Coupling," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

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Refer to NPO-20586, volume and number of this NASA Tech Briefs *issue, and the page number.*

Time-Parallel Algorithms for Solving PDEs

A report presents additional details about a class of massively parallel algorithms for finite-difference numerical solution of time-dependent partial differential equations (PDEs). Some aspects of these algorithms were described in two previous articles in *NASA Tech Briefs*; namely, "Massively Parallel Computation of Electromagnetic Fields" (NPO-19453), Vol. 26, No. 5 (May 2002), page 72 and "Time-Parallel Solutions of Linear PDEs on a Supercomputer" (NPO-19385), Vol. 23, No. 12 (December 1999), page 24. These algorithms are fully parallelized in time as well as in space: this is achieved via a set of transformations based on eigenvalue/eigenvector decompositions of matrices obtained in discretizing the PDEs. Among other things, the report discusses efficient techniques for computing these decompositions for PDEs in which the spatial part involves Laplace's or Poisson's equation in two-dimensional Cartesian or polar coordinates.

This work was done by Amir Fijany, Jacob Barhen, and Nikzad Toomarian of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Time Parallel Algorithms for Solution of Time-Dependent Partial Differential Equations (PDEs)," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*
NPO-19433

Specifying Fiber Alignment System Performance:

Coupling Loss Offers An Alternative to Motion Capability

One of the most difficult assembly tasks ever introduced into commercial manufacturing is the sub-micron alignment and attachment of a fiber-optic to a laser diode or other optical waveguide. Consequently, many questions arise about how to specify and ultimately verify the performance of the positioning system(s) that will guide these microscopic elements successfully into alignment. Proper alignment is critical to assuring the long-term performance of fiber-optic components.

Precision motion performance is usually discussed in terms of "resolution," but in fact there are multiple performance attributes that must be addressed in order to be consistently successful in fiber-optic device alignment applications. This article defines key terms for motion systems, discusses the importance of each with respect to this very demanding process, and offers a method for specifying motion systems in terms of coupling loss rather than motion capability.

Fundamental Motion Terminology

There are four important figures of merit for motion stages. They are resolution, minimal incremental motion (MIM), repeatability, and stability.

Resolution is used for Encoder Feedback Resolution (EFR) and is the smallest increment for determining the position of a stage. EFR describes only position reading and is not the same as the Minimum Incremental Motion.

Minimum Incremental Motion (MIM) is the smallest motion a positioning device is capable of reliably moving. MIM describes actual motion and is influenced by several factors like encoder resolution, stage, and controller closed loop quality.

Repeatability is the ability of a motion system to reliably achieve a commanded position over many attempts. There are two types of repeatability, uni-directional (UDR) and bi-directional (BDR). BDR is more stringent, and for fiber-optic alignment applications requires closed-loop positioning control with direct drive and on-axis encoder feedback. As it turns out, BDR and MIM are linked which allows us to use the approximation: BDR= +/- *MIM*

Stability is the ability to maintain a constant position over a specified period of time.

Of these four parameters, MIM (and so BDR) is the most significant when defining a motion system to achieve maximum fiber coupling. Because MIM relates to the ability of the motion system to take smaller steps while searching for the optimal location, a stage with a smaller MIM will theoretically find the highest coupling point. In practice however, most fiber-optic devices have coupling maxima that are of much greater width than the MIM of the alignment system. This means that decreasing MIM beyond a certain point will no longer have a measurable effect on the overall alignment efficiency. The importance of BDR is necessitated by the device attachment application, which requires the alignment system to (repeatedly) return a fiber to the position of maximum coupling during the attachment process.

Stability is also essential because after alignment the remaining steps, such as attachment, require the coupling efficiency to be held constant over the period of time needed for completion. Although resolution contributes to MIM, it is not a critical parameter in fiber-optic device alignment applications. If a stage cannot move in very small steps (MIM), even very high-resolution readings of position become irrelevant.

Stage specifications such as MIM, stability and resolution are typically given per stage axis as if the stage was used by itself. Since fiber alignment systems are composed of many stages stacked together, the motion system must be spec-

Motion systems for fiber-optic device alignment & attachment, such as the Newport AutoAlign™-MDX, are being specified in terms of coupling loss (dB).

ified rather than a single stage axis. Furthermore, the true MIM, stability, and resolution at the tool point (where the fiber meets the device) are much different than at the stage encoder. In order to establish the exact MIM at the tool point, sophisticated experimental setups are needed, normally using non-contact measurements. Although interferometric measurements would be the most precise, it's relatively difficult to implement for the typical user. A simpler alternative is to use the power coupling efficiency of two single-mode fibers.

A Simpler Alternative

Achieving the maximum coupling point during alignment is a function of the previously outlined parameters, the alignment algorithm and its ability to search out and seek the maximum point, and other factors including environmental characteristics. So rather than specifying a motion system in terms of MIM, resolution, and other motion related criteria, specifications should be defined in terms of power coupling efficiency.

All specifications should be easily measurable by both the customer and the vendor. They should also relate to the performance characteristics of the system in a way that is understood to the user. Lastly, part of the specification should address overall system performance rather than the performance of its individual parts. This is particularly important since alignment systems are complex systems consisting of motion stages, vibration isolation, optical power measurements, and alignment algorithms. The following method for specifying alignment systems addresses these criteria.

The experimental setup to verify these specifications is quite simple and consists of two single-mode fibers. Light passes through one fiber into the other. The alignment system will align these two fibers so that there is maximum light coupling. The test conditions are as follows:

System Setup: Two single-mode fibers are separated by a specified distance z in the optical axis. One fiber is on a stationary stage. The other is on the alignment system to be tested.

Load on the System: The load on the system is W.

Temperature Range: The system will operate within a temperature range K and achieve the above specifications, except for stability (S) specification, which has its own specified range.

Number of Measurements: The range and standard deviation of each specification is measured using at least 50 observations.

The Specifications

Motion Repeatability is defined by R_σ (dB). It is determined by achieving alignment, recording the motion coordinates and the coupling power, and then commanding the system to return to the same coordinates and record the power for at least 50 more repetitions. R_σ is the standard deviation of these measurements. This measurement is a system level measurement that takes into account all the system parameters.

Maximum Coupling Efficiency is defined by two parameters. The average coupling-loss C (dB). This specification is a measure of how good the coupling is, and is determined by achieving alignment, recording coupling efficiency, then moving all axes (except Z) away from the aligned position, and then aligning again and recording power.

Alignment Repeatability is defined by the coupling loss standard deviation C_σ (dB) measured as described above. C and C_σ are also system level performance measurements that take into account all the system parameters including the alignment algorithm.

Alignment Stability is defined by the drift, S (dB), in coupling loss recorded over a period of t minutes after alignment has been achieved, while the temperature fluctuation is limited to a range $K(s)$. When determining this specification, the alignment system is kept idle.

Alignment Time is defined by the average time, T in seconds, required by the alignment system to reach maximum coupling efficiency from observation of first light.

Fiber-to-fiber alignment does not cover all applications. Since single-mode fibers are standard, it provides a universal apparatus to test alignment systems. The user may have other applications where they are aligning lasers to fibers or waveguides to fibers, but those applications are dependent on the device in question and do not provide a universal means for system specification.

How will MIM effect the coupling efficiency specifications? If two fibers are in perfect alignment, movement in the X or Y-axes will result in lower coupling between them. Based on theoretical models, a 50nm movement in X or Y will only result in <0.001 dB additional loss. This difference cannot usually be measured but is calculated from a theoretical model. In general, 50nm MIM is sufficient for most alignment applications.

As standards emerge in the fiber-optic industry for performance of components, similar set of standards are needed for the performance of automation systems, particularly alignment systems. Both the user and the vendor can easily measure the suggested performance criteria. It can also be used as acceptance level tests or used to compare the performance of different systems.

The authors can be contacted by email at Guy Bouvree (Applications Manager, Motion Systems), gbouvre@newport.com; Frank Vodhanel (Product Manager, Fiber Alignment Systems), Fvodhanel@newport.com; and Sohrab Zarrabian (Sr. Director of Product Management), szarrabian@newport.com, or call (949) 862-3400.

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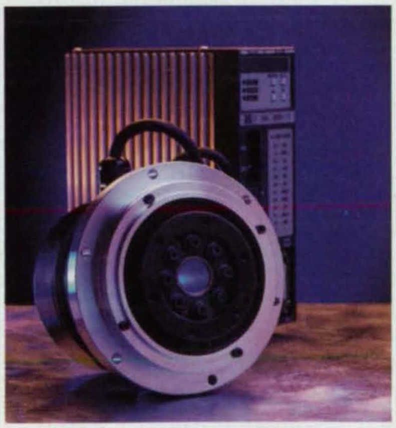

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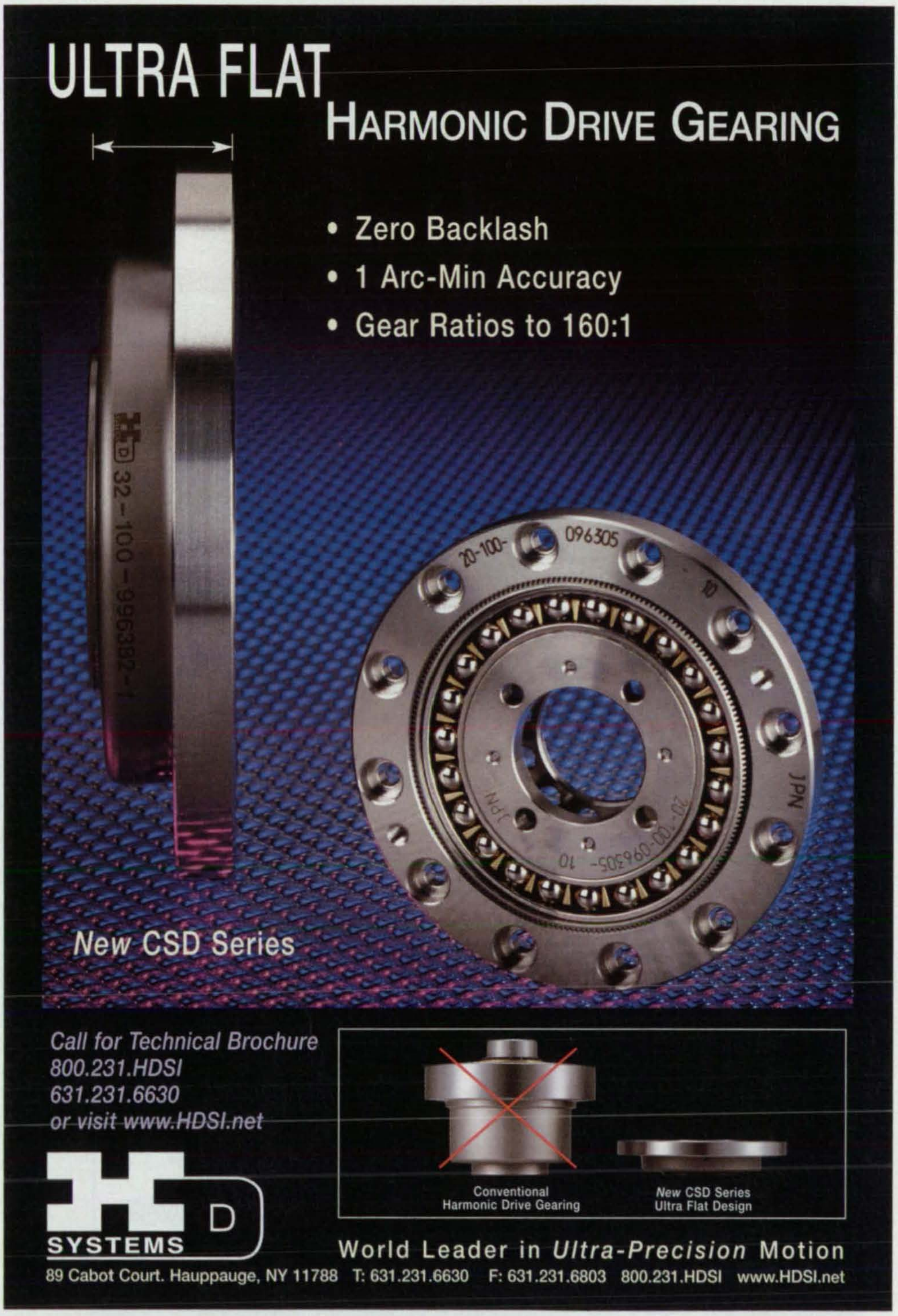

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Algorithm Computes Kinematics of a Rover on Rocky Terrain

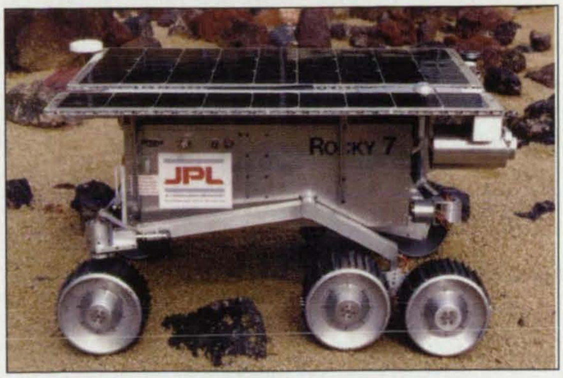
This algorithm is efficient enough for use in a real-time simulation.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Rover Analysis Modeling and Simulation (ROAMS) algorithm is to solve the kinematics of a wheeled mobile robot (rover) traversing on a rocky terrain. The rover is constructed using a "rocker-bogey-differential" type suspension and steering system as shown in the figure. By exploring the mechanical symmetry and the wheeled-terrain contact characteristics on a rough terrain profile, we developed a novel algorithm to carry out the rover's configuration, including the vehicle's wheels, steering and suspension linkages, and the position and orientation of the chassis. Because of its efficient and reliable numerical results, the ROAMS algorithm is well suited for the real-time simulation test bed, e.g., a simulation software system, of the mobile robotic vehicles in the planetary surface exploration missions. Currently, it is used to support the development of simulation and operation tools for the Mars Exploration Rover (MER) in the Mars '03 mission.

One of the most important properties of the algorithm is the robust computational result, which yields a fast prediction of the rover's position and orientation in an uncertain environment. The ROAMS algorithm treats the underlying mathematical model as an inverse-kinematics problem, and carries out the solutions using the computational techniques for constrained optimization. In this framework, the objective functions comprise three conditions: (1) rover's internal differential mechanisms, (2) wheel-terrain contact, and (3) rover's driving motion. The resultant nonlinear equations can be derived, and their solution can be computed by a straightforward application of numerical methods. However, the standard approaches to this nonlinear system of equations suffer from the instability and inefficiency in the numerical solutions due to the rough terrain profile, which is often modeled as a piecewise smooth digital elevation map (DEM). Moreover, the modeling of the physical limits of the linkages (e.g., the bumper-stops) can be problematic to the solution, as well as the case that all wheels may not be in contact with the ground at all times. All these modeling and numerical difficulties are resolved in the novel algorithm that achieves the real-time simulation of the rover traversal on a rocky terrain.

In this algorithm, we implemented a Newton-type iterative method that handles the non-smooth wheel-terrain contact equations using global searching and relaxation techniques. The solution also takes account for the bump-stopper devices, which have been modeled as the joint limits at the corresponding linkages, and maintains a fast convergent rate. Regular Newton-type iteration requires the smoothness of the equations to ensure a fast convergence. This prerequisite of a robust convergence is violated since the roughness of the terrain has been embedded in the contact equations. When the rocker or bogey linkages reach their limits, an abruption of the iteration can induce



Rocky-7, a small robotic vehicle, is designed to traverse rocky terrain. The algorithm described in the text solves the inverse kinematic problem of the rover/terrain system during a computational simulation of such a traversal.

unpredictable solution of the configuration. To overcome these numerical difficulties, we applied a weight factor to the residual of each contact equation. During the iterations, the weight factor for a given wheel can be made to approach zero to relax the contact condition. Whenever the wheel leaves the ground, its corresponding weight factor is set to zero for a total relaxation of this wheel-terrain contact. The re-scaling of the weight factors is coupled with the global search algorithm, which can detect the joint limits (associated with each of the wheel-terrain contacts) for locking the joints, and can sample small perturbations around the contacting locations to determine the occurrence of a separation of the wheel and the ground.

The step-selection strategy used in the global search is a backtracking line search algorithm that monitors the progress of the iteration. For a smooth terrain profile, the iterative solution generated by the Newton method converges very rapidly to a local minimum of the nonlinear equations. However, the rate of convergence can be tremendously decreased when a non-smooth terrain profile appears. Special cares have to be taken to maintain robust and efficient solution in the case of non-smooth terrain profile. Although the problem in hand is ill-posed (i.e., it is well-known that the Newton method cannot treat non-smooth equations), we developed a heuristic solution to ease the computational difficulty in the iterations. In practice, the wheel-terrain contact is treated as a non-penetrative type, which is not a realistic portrait of the nature of the wheel-terrain interaction. Therefore, a search direction to the wheel-terrain contact may not be in-line with the normal direction of the terrain (at the contact location), instead, it could be anywhere along the perimeter of the wheel. The heuristic solution leads to modeling the wheel-terrain contact equation as the distance constraint between the wheel center and the terrain profile. As shown in all the preliminary testing cases, the modification of contact equations yields a much-improved convergence in non-smooth terrain profiles, and allows the modified Newton iteration to overcome many local irregularities.

This work was done by Jeng Yen of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
NPO-20997

Software for Simultaneous Control of Three Magnetic Bearings

John H. Glenn Research Center, Cleveland, Ohio

Five-Axis, Three-Magnetic-Bearing Control Code (FATMaCC) is a C++-language computer program for controlling a magnetic thrust bearing in one degree of freedom and two magnetic radial bearings, each in two degrees of freedom. These bearings levitate a vertical-axis rotor for experiments on the effects of vibrations on turbomachinery. When executed on a 1-GHz processor, FATMaCC can control the bearing/rotor motions in either a decentralized or a centralized (modal-control) manner at a loop time of 56 μs. Through keyboard entries, the user can modify such bearing parameters as stiffness, damping, and bias. A module in the program generates signals that can be superimposed on the radial-bearing x- and y-axis control signals to generate forces that excite rotor vibrations. There is an option to modulate the radial bearing control signals with cosine and sine functions, to make the radial excitation force vector rotate about the nominal central bearing axis. There is also an option to excite rotor rigid-body modes; depending on the polarities of the excitation signals ap-

plied to the radial bearings, either the bounce or the tilt mode is excited.

This program was written by Carlos R. Morrison of **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17293.

Crowned Races for Crossed Roller Bearings

Scuffing would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

Crowned races have been proposed for crossed roller bearings. Crowning of the races is expected to reduce scuffing of the cylindrical rollers. Crowning of the races is expected to be especially beneficial in bearings made of polymers (instead of metals) to reduce weight.

The crossed-roller bearing design is the roller equivalent of the x-type ball bearing design. In a crossed-roller bearing, the races are conical surfaces at angles of 45° to the axis of rotation. The advantages and disadvantages of the ball and crossed-roller designs are complementary: In comparison with ball bearings, roller bearings can withstand greater loads. On the other hand, roller bearings are more susceptible to scuffing, which is caused by a kinematic mismatch between tangential roller speeds at the inner and outer diameters of the races.

In a crossed-roller bearing with crowned races (see figure), the contact area, and thus the amount of scuffing, would be reduced (relative to that of conical races) to a value near that of ball bearings. The crown radius is a free design parameter that can be chosen, along with other parameters, in consideration of the bearing material(s) and the loads that must be borne in a given application.

One might ask why it would be preferable to crown the races instead of crowning the rollers. The reason is a practical one: Unlike in the case of steel bearing balls, it is difficult to fabricate polymeric bearing balls or polymeric crowned rollers with sufficient precision to ensure sharing of loads as needed for long bearing life. On the other hand, cylindrical crowned rollers of sufficient precision can be fabricated easily by centerless grinding in conventional machines.

This work was done by Donald Bickler of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
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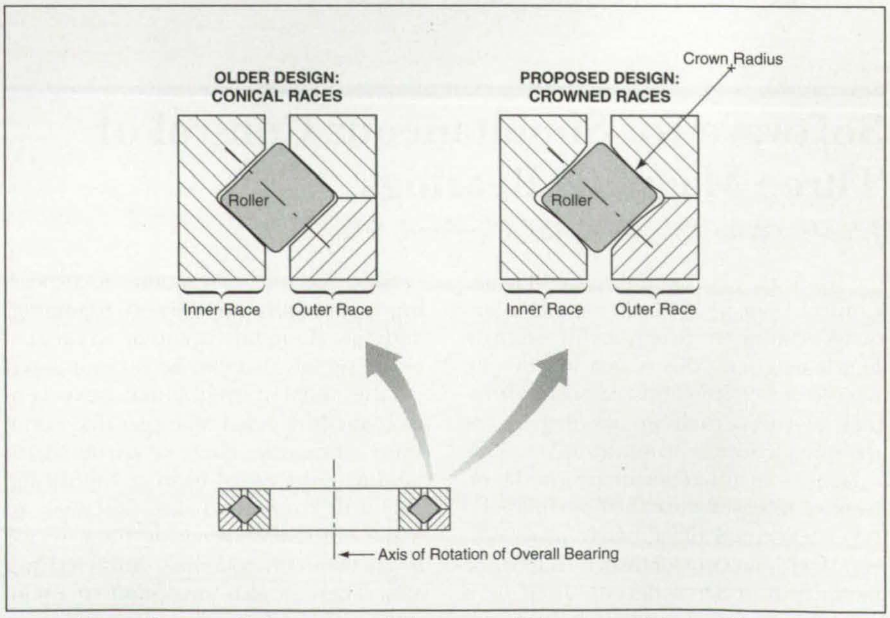
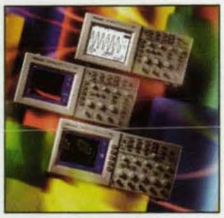


Crowned Races, in contradistinction to conical races, would function with less scuffing in roller/race contact areas.

New on the MARKET

Digital Oscilloscopes



The TDS1000 and TDS2000 series digital storage oscilloscopes from Tektronix, Beaverton, OR, feature a Fast Fourier Transform (FFT) function to analyze, characterize, and troubleshoot circuits, and a color LCD display. The TDS2000 family is available in 2- and 4-channel versions, delivering up to 200 MHz bandwidth and 2 GS/s maximum sample rate. The TDS1000 are 2-channel instruments with a 1 GS/s maximum sample rate and bandwidth up to 100 MHz. **For Free Info Circle No. 700 or Visit www.nasatech.com/tektronix**

Waveform Digitizer Cards

Gage Applied, Montreal, Canada, has released CompuScope waveform digitizer cards for the CompactPCI bus that offer sample rates for 8-bit, 14-bit, and 16-bit sampling resolution. The CompuScope 85Gc features 5 GS/s sampling and 500-MHz bandwidth on two simultaneous channels. The CompuScope 1610C features 16-bit vertical resolution at a 10 MS/s sampling rate for two simultaneous channels. **For Free Info Circle No. 701 or Visit www.nasatech.com/gage**

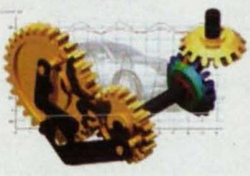
Rugged Notebook Computer

Dolch Computer Systems, Fremont, CA, offers the NotePAC™ industrial notebook computer featuring an integrated full-color inkjet printer protected by an all-metal enclosure. The printer assembly is attached to the NotePAC via a machined interface plate and high tensile screws to form a single, portable unit. The printer is battery powered and is suitable for emergency services, the military, public utilities, and other field services. **For Free Info Circle No. 702 or Visit www.nasatech.com/dolch**

Sensor/Transducer System

Transducer Techniques, Temecula, CA, has combined its SWS socket wrench torque sensor and its PHM-100 handheld transducer indicator into one system, providing measurements of bolt or nut wrenching torques in either direction. The PHM-100 has a peak hold feature that captures at less than one millisecond and operates on a 9-volt battery for 60 hours. The SWS is a reaction-type torque sensor offered in six ranges from 10 to 1000 ft. lbs. full scale. **For Free Info Circle No. 703 or Visit www.nasatech.com/tt**

Motion and Stress Simulation



MSC.visualNastran 4D 2002 from MSC.Software, Santa Ana, CA, is a Windows-based software that sets 3D assemblies into motion, animating the resulting stresses. It supports most CAD systems through integration with Autodesk Inventor™ and Mechanical Desktop®, Pro/ENGINEER®, SolidWorks®, and Solid Edge®, and standard file formats. Features include analysis of rigid body dynamics, vibration, deflection, buckling, steady state heat transfer, redundant constraint relief, and photo-realistic rendering. **For Free Info Circle No. 704 or Visit www.nasatech.com/msc**

New LITERATURE

Pressure and Flow Instruments

The CONTROLCAT™ New Horizons® in Pressure, Flow & Everything Else handbook from OMEGA Engineering, Stamford, CT, features information on conductivity and dissolved oxygen meters, controllers and transmitters, and handheld instruments for pH, temperature, pressure, and airflow. The handbook also features load cells, flow meters, signal conditioners and switches, and industrial pressure transducers and transmitters. **For Free Info Circle No. 706 or Visit www.nasatech.com/omega**

O-Ring Seals

Parker Hannifin Seal Group, Irvine, CA, has released a catalog describing product forms and applications for its o-ring seals. Applications include automotive systems, chemical processing equipment, medical devices, aerospace vehicles, and ultra-high-purity semiconductor processing. Also included are the compound mixing and tooling operations used to manufacture the seals. **For Free Info Circle No. 707 or Visit www.nasatech.com/parker**

Data Acquisition Systems

The DAQ Designer™ 2002 CD from National Instruments, Austin, TX, helps users select software and hardware products for their custom data acquisition systems. Users answer questions about their application details, and the configuration advisor recommends the best software and hardware for applications in acoustic/vibration, inspection and placement, data logging and low-frequency sourcing, signal acquisition and generation, control and simulation, and data management. **For Free Info Circle No. 708 or Visit www.nasatech.com/ni**

Paperless Recorders

Monarch Instrument, Amherst, NH, offers a brochure highlighting its Data-Chart® paperless recorders that accept up to 12 direct universal inputs including thermocouples, RTDs, DC voltage, current, and dry contact. Information is displayed on LCD displays and recorded to 3.5" disk, 100 MB Zip disk, or PCMCIA cards. **For Free Info Circle No. 709 or Visit www.nasatech.com/monarch**

Plastic Fasteners and Components

A 368-page catalog of plastic fasteners and components is available from Craftech Industries, Hudson, NY. The catalog includes ANSI and DIN standard machine screws, cap screws, nuts, washers, spacers, hinges, handles, u-bolts, eye bolts, wire handling hardware, tube and hose fittings, caps and plugs, and panel fasteners. More than 80 materials are available. **For Free Info Circle No. 710 or Visit www.nasatech.com/craftech**

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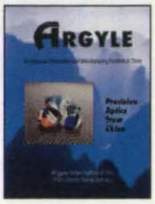

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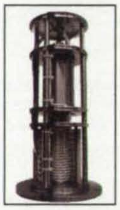

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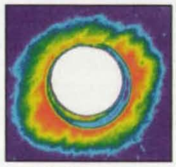

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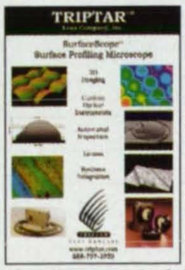

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